AD-A086 470 AERONAUTICAL RESEARCH LABS MELBOURNE (AUSTRALIA) F/G 1/3
FATIGUE DAMAGE ESTIMATION FOR THE BAEA AIRCRAFT FATIGUE DATA AN--ETC(U)
AUG 79 R C FRASER
UNCLASSIFIED ARL/STRUC-TM-297 NL

| OF |
AD
A086470

END
DATE
FILMED
8-80
DTIC

UNCLASSIFIED

ARL-STRUC-TECH-MEMO-297

LEVEL

AR-001-761

ADA086470

AUSTRALIA

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

AERONAUTICAL RESEARCH LABORATORIES

MELBOURNE, VICTORIA

Structures Technical Memorandum 297

FATIGUE DAMAGE ESTIMATION FOR THE BAeA AIRCRAFT FATIGUE DATA ANALYSIS SYSTEM.

R.C. FRASER

DTIC ELECTE JUL 14 1980 C

THE UNITED STATES NATIONAL TECHNICAL INFORMATION SERVICE IS AUTHORISED TO REPRODUCE AND SELL THIS REPORT

DDC FILE COPY

Approved for Public Release.

THIS DOCUMENT IS BEST QUALITY PRACTICABLE. THE COPY FURNISHED TO DDC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

© COMMONWEALTH OF AUSTRALIA 1979

COPY No 20

AUGUST 1979

UNCLASSIFIED

80 7 11 002

DISCLAIMER NOTICE

THIS DOCUMENT IS BEST QUALITY PRACTICABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

AR-001-761

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANIZATION

AERONAUTICAL RESEARCH LABORATORIES

Structures Technical Memo~~randum~~ 297

FATIGUE DAMAGE ESTIMATION FOR THE BAeA AIRCRAFT FATIGUE DATA ANALYSIS SYSTEM.

R. C. FRASER

DTIC
ELECTE
JUL 14 1980
S D
C

SUMMARY

The estimation of fatigue damage from the strain range pair data generated by the airborne component of the BAeA Aircraft Fatigue Data Analysis System is described.

POSTAL ADDRESS: Chief Superintendent, Aeronautical Research Laboratories, P.O. Box 4331, Melbourne, Victoria 3001, Australia.

This document has been approved for public release and sale; its distribution is unlimited.

DOCUMENT CONTROL DATA SHEET

Security classification of this page: UNCLASSIFIED

1. DOCUMENT NUMBERS
a. AR Number:
AR-001-761
b. Document Series and Number:
Structures Technical Memorandum 297
c. Report Number:
ARL-STRUC-TECH-MEMO-297

2. SECURITY CLASSIFICATION
a. Complete document:
UNCLASSIFIED
b. Title in isolation:
UNCLASSIFIED
c. Summary in isolation:
UNCLASSIFIED

3. TITLE:

FATIGUE DAMAGE ESTIMATION FOR THE BAeA
AIRCRAFT FATIGUE DATA ANALYSIS SYSTEM.

4. PERSONAL AUTHOR:

FRASER, Robert C.

5. DOCUMENT DATE:
August, 1979

6. TYPE OF REPORT AND PERIOD COVERED:

7. CORPORATE AUTHOR(S):
Aeronautical Research Laboratories

8. REFERENCE NUMBERS
a. Task:
AIR 78/052
b. Sponsoring Agency:

9. COST CODE:
24 1045

10. IMPRINT
Aeronautical Research Laboratories, Melbourne

11. COMPUTER PROGRAM(S)
(Title(s) and language(s)):
RPDAM.F4 Fortran
DATAIN.F4 Fortran
DAMAGE.F4 Fortran
DAMOUT.F4 Fortran
INTEP1.F4
INTEP2.F4
INTEST.F4
DAMOLD.IN

12. RELEASE LIMITATIONS (of the document):

Approved for Public Release.

12-0. OVERSEAS:	N.O.		P.R.	1	A		B		C		D		E	

13. ANNOUNCEMENT LIMITATIONS (of the information on this page):

No limitation.

14. DESCRIPTORS:
Fatigue life
Aircraft
Data recorders
Stress Cycle

15. COSATI CODES:
2012
0103

16. ABSTRACT:

The estimation of fatigue damage from the strain range pair data generated by the airborne component of the BAeA Aircraft Fatigue Data Analysis System is described.

CONTENTS

Accession For
NTIS GRA&I
DDC TAB
Unannounced
Justification

By
Distribution/
Availability Codes

Dist	Avail and/or special
A	23

1. INTRODUCTION

The Aircraft Fatigue Data Analysis System (AFDAS) is designed to provide a reliable, concise and cost effective method of monitoring the condition of up to eight fatigue critical locations on an operating aircraft structure. It represents a significant advance on existing in-service fatigue monitoring systems because:

1. It uses a direct measure of loading environment - strain.

2. It uses a method of load cycle counting that has been found to be closely related to the fatigue process - the range pair method[2-7].

3. Utilization of modern advances in microelectronics has resulted in a small and reliable airborne instrument.

4. The tabular form used for the storage of range pair data allows a flexible and simple fatigue damage calculation.

The four basic sub-systems of AFDAS are the:

1. Strain gauge transducers.

2. Strain Range Pair Counter (SRPC).

3. Interrogator Display and Readout Unit (IDRU).

4. Fatigue Damage Computer Program

and of these 1 to 3 are described in detail in Ref. 1. This description will outline the fatigue damage estimation procedure i.e. sub-system 4.

2. THE STRAIN RANGE PAIR

When a test specimen is stressed by a load varying sinusoidally in time the fatigue life that results is essentially independent of the cyclic frequency. Consequently the fact that only a sequence of load turning points is required to define a load environment is the first important consideration in estimating the service life of a particular structure.

Secondly, most fatigue test data used for life estimation have been obtained by cycling test specimens under constant amplitude loads and presenting the results as a plot of cycles to failure (N) against

alternating stress (S), (hence the term S-N data). Thus, to conform with this approach of a fatigue life defined by cycles the turning points of a non-constant amplitude sequence must be paired into cycles relevant to both the fatigue process and to the S-N data available.

Many different cycle counting methods exist for this purpose[2] and of these the rainflow and range-pair (sometimes called range-mean-pair) methods have been recognised as being the most useful from a theoretical point of view, primarily because both identify load cycles in terms of the stable cyclic stress-strain behaviour of the material concerned.[4-7] (i.e. they pair turning points into cycles which relate to closed stress-strain hysteresis loops). The major difference between the two methods is that the rainflow method counts in terms of half cycles whereas the range pair method will reduce a load history to a set of complete load cycles. (When the rainflow method is constrained to count in full cycles both methods produce identical results although the range-pair method is inherently far simpler).

In the absence of end effects[10] the range pair may be defined as that pair of turning points which can be clearly identified as a perturbation of a larger cycle. Referring to Fig. 1 the cycle x_2, x_3 is clearly a perturbation of the larger cycle x_4, x_1 and thus forms a range pair. In mathematical terms this definition can be expressed so:

if $|x_1-x_2| >= |x_3-x_2| <= |x_3-x_4|$ then the cycle x_2, x_3 constitutes a range pair.

By removing range pairs from the load sequence as they are detected, closing the gap and repeating the test above, an entire sequence of load turning points will be eventually reduced into a set of range pairs as shown in Fig. 2.

However, because the range pair method does not spuriously ignore the presence of any turning point in the load history processed, the number of range pairs generated from long load sequences, (in flight, load sequences may be of an unknown and unlimited length) can be large and an efficient means of recording this data is necessary. The range pair table not only fulfils this need but also presents range pair data in a format that is convenient for fatigue life calculations. The strain range-pair table is simply a half array of cycle counts produced by grouping the range pairs obtained from a load sequence into a number of cells depending on the values of their troughs and peaks.

If the load experienced by a particular structural item is known to lie always between the values L_{min} and L_{max} then dividing this load range into N_L levels of $(L_{max}-L_{min})/N_L$ in size provides a simple method of grouping range pairs. Consider Fig. 3 where the range pair of load x_1 to x_2 is shown. Because its trough lies in level 1 and its peak

in level 1+p it can be termed a range pair of level 1 to level 1+p. Consequently the cell in the range pair table of Fig. 4 which corresponds to these level values would record a cycle count of 1. All the range pairs in the load history whose trough and peak were likewise in levels 1 and 1+p respectively would thus be represented in the range pair table by a correspondingly large count in the same cell. Similarly, all the other range pairs of the load history processed would be grouped into their respective cells to complete the range pair table. References 2 and 9 detail the characteristics of the range pair table and some of its many uses in fatigue related areas. The SRPC of AFDAS uses a 16 level division of load range as the basis of its strain range pair grouping procedure. However, because jitter (induced electronically or by low levels of aircraft vibration etc.) within or about level boundaries would produce a large number of counts not related to the actual load history the corresponding range pairs of level 1 to level 1 and level 1 to level 1+1 are ignored i.e. the two leading diagonals of its strain range pair table are discarded. One characteristics of the range pair table is that diagonals down left to right as in Fig. 5 represent range pairs with the same alternating load. Thus it can be seen that the two leading diagonals represent those range pairs with the smallest alternating loads and consequently those with the least contribution to the fatigue damage of the monitored structure. Fig. 5 illustrates the strain range pair table produced by the SRPC of AFDAS.

3. FATIGUE DAMAGE ESTIMATION

The problem of predicting the service life of aircraft structures under fatigue loading with a high degree of accuracy has existed for some time. Since the linear cumulative damage rule became widely known thirty years ago[8] its deficiencies have inspired many modifications and alternative theories though it is still the most generally used.

The hypothesis that a load cycle in a variable amplitude loading sequence will cause the same damage to a structure as that due to a cycle in a constant amplitude load sequence of the same load level, forms the basis of the linear damage rule, e.g. if it has been determined experimentally that a test specimen relevant to the structural element under consideration lasts N cycles when subjected to a constant amplitude load sequence of a certain mean and alternating load value, then one cycle of the same mean and alternating load that occurs in the operating environment of the part can be said to cause 1/N of the damage necessary to cause its failure. Thus when the results of many such constant amplitude tests are available (usually presented in the form of S-N curves as previously mentioned, e.g. Fig. 6) the damage contribution

of every range pair cycle can be determined and summed to give the total damage sustained by the structure. This linear cumulative procedure is usually expressed as:

$D = \Sigma(n_i/N_i)$ Where D = total damage value (failure occuring when D = 1, or 10^6 μ_f when measured in microfails*)
n_i = number of cycles at a particular load range $M_i = S_i$
N_i = average number of cycles to cause failure at the i-th load range.

When the cycle information stored in the range pair table is to be used in a fatigue calculation of this sort the mean and alternating load equivalents of each cell in the table must be determined. From Fig. 7 it can be seen that the n range pairs in the cell of level l to level l+p can be interpreted load-wise as n range pairs of load $L_{min}+(l-.5)L_{SZ}$ to load $L_{min}+(l+p-.5)L_{SZ}$. (The inherent assumption that the range pairs are distributed within the given levels such that their mean load value can be taken to be the mean load value of the level has been found to be a reasonable approximation provided the number of levels used for the table is not too small[9]). Hence the mean and alternating load values of the counts in the given cell can then be determined from these trough and peak load values (called L_i and L_j respectively) as $(L_j+L_i)/2$ and $(L_j-L_i)/2$ to permit the determination of N. The damage increment attributable to the given cell of the range pair table is as before simply n/N. The same procedure is used to determine the damage value of every cell in the strain range pair table and subsequently, by summation, the total damage estimate for the load sequence it represents.

In the program listed in the Appendix if a range of tabulated S-N data is exceeded then linear extrapolation is resorted to. Unless the range of tabulation exceeds that of the range-pair table or the data is carefully close this can cause inconveniences.

---

* Since the damage values calculated for each flight load sequences are usually very small fractions of one, it is convenient to multiply them by 10^6 to obtain more manageable numbers, termed microfails.

As has already been mentioned range pair table diagonals down left to right represent sets of range pairs with the same alternating load. Thus by plotting the damage value summed for each diagonal, against its alternating load a damage density histogram can be obtained which will define the areas in the load environment causing the most fatigue damage.

Since the measurement of load used by the SRPC is strain, and S-N data is usually presented in the form of stress versus fatigue life, Young's Modulus (E) for the material of the structural element being monitored is also required. Thus in summary I_{min}, I_S, E and the appropriate S-N data for each of the eight channels being monitored are required to process the output from the SRPC. Fig. 8 illustrates the procedure described above for the estimation of fatigue damage from the strain range pair data of the SRPC using a linear cumulative law.

A Fortran IV computer program used to process the strain range pair data from the SRPC is described in the appendix to demonstrate one implementation of the simple damage estimation method discussed.

4. CONCLUSION

A procedure for predicting the service life of aircraft structures from strain range pair data obtained by the Strain Range Pair Counter (SRPC) of the Aircraft Fatigue Data Analysis System (AFDAS) has been described.

Based on a linear cumulative damage law the simple elegance of the method (due in part to the tabular nature of SRPC data) allows for a flexible implementation as a computer program.

Due to the small amount of range pair data and subsequent processing involved, the logistic benefits of using AFDAS for fatigue life monitoring purposes, must be considered substantial.

REFERENCES

1.		The Aircraft Fatigue Data Analysis System. BAeA Report, October 1978. BAeA, Contractors Area, DRCS, Salisbury South Australia.
2.	Ford, D. Patterson, A.K.	A Range Pair Counter for Monitoring Fatigue. ARL Tech. Memo. 195, January 1971.
3.	Schijve, J.	The Analysis of Random Load Time Histories with Relation to Fatigue Tests and Life Calculations. ICAF-AGARD Symposium, Paris, May 1961.
4.		Fatigue Life Estimation Under Variable Amplitude Loading. E.S.D.U. Fatigue Sub-Series, Item 77004.
5.	Matsuiski, M. Endo, T.	Fatigue of Metals Subjected to Varying Stress. Proceedings of Kyushu Meeting of Japan Society of Mechanical Engineers, Japan, March 1968.
6.	Dabell, B.J. Watson, P.	Cycle Counting Fatigue Damage. Statistical Aspects of Fatigue Testing Symposium, Warwick University, February 1975.
7.	Powling, N.B.	Fatigue Failure Predictions for Complicated Stress Strain Histories. Journal of Materials. JMSLA 7(1), March 1972.
8.	Miner, M.A.	Cumulative Damage in Fatigue. Journal of Applied Mechanics, ASMB Vol. 12, 1945.
9.	Fraser, R.C.	A One Pass Method for Counting Range Mean Pair Cycles for Fatigue Analysis. ARL Structures Note 454, June 1979.
10.	Acton, F.S.	Numerical Methods that Work. Harper and Pow, New York, 1970.

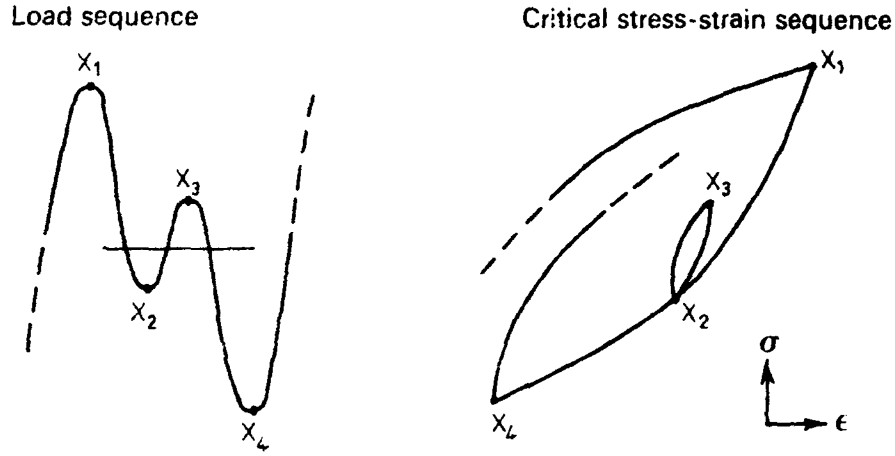


FIG. 1 : PERTURBATION DEFINITION OF THE RANGE PAIR

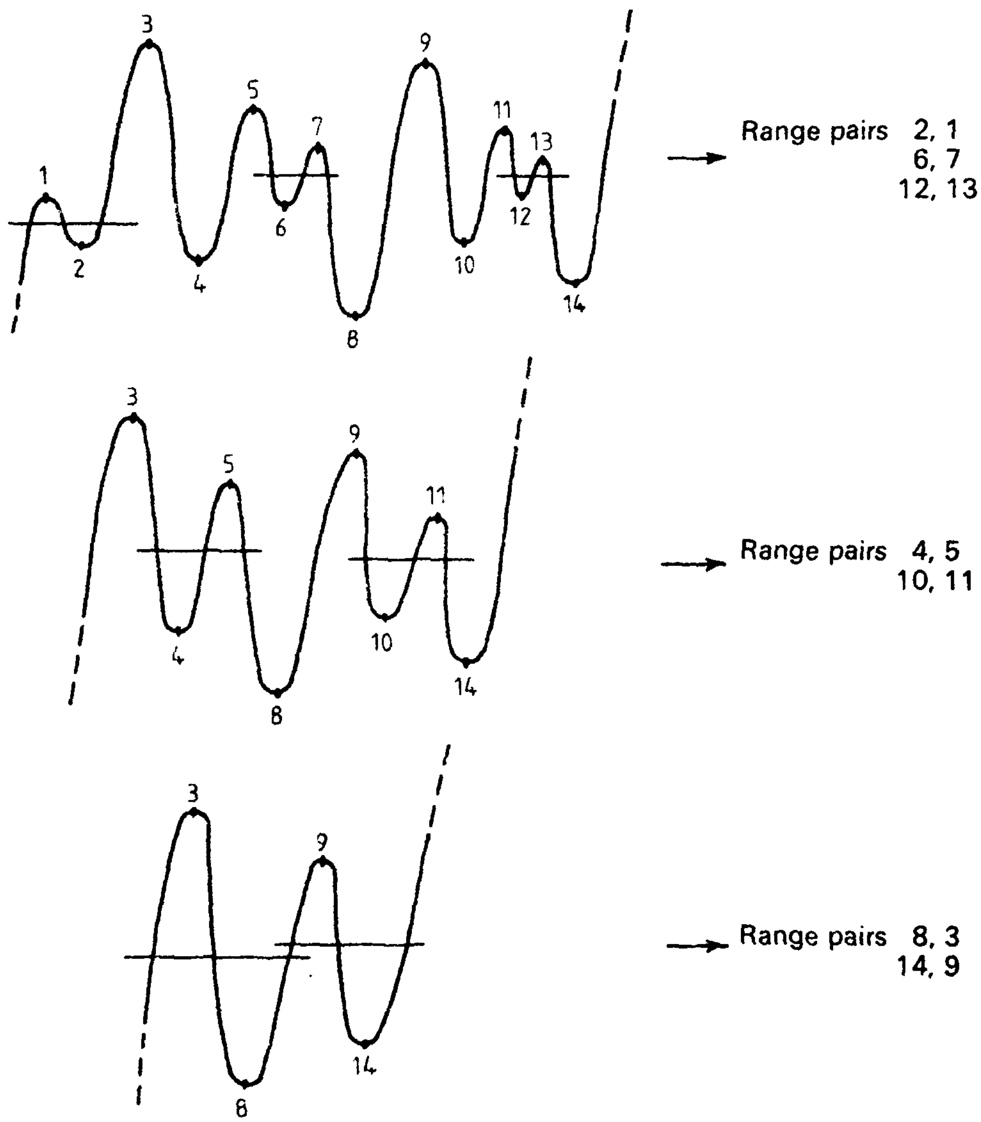


FIG. 2: EXTRACTION OF RANGE PAIRS FROM A LOAD SEQUENCE

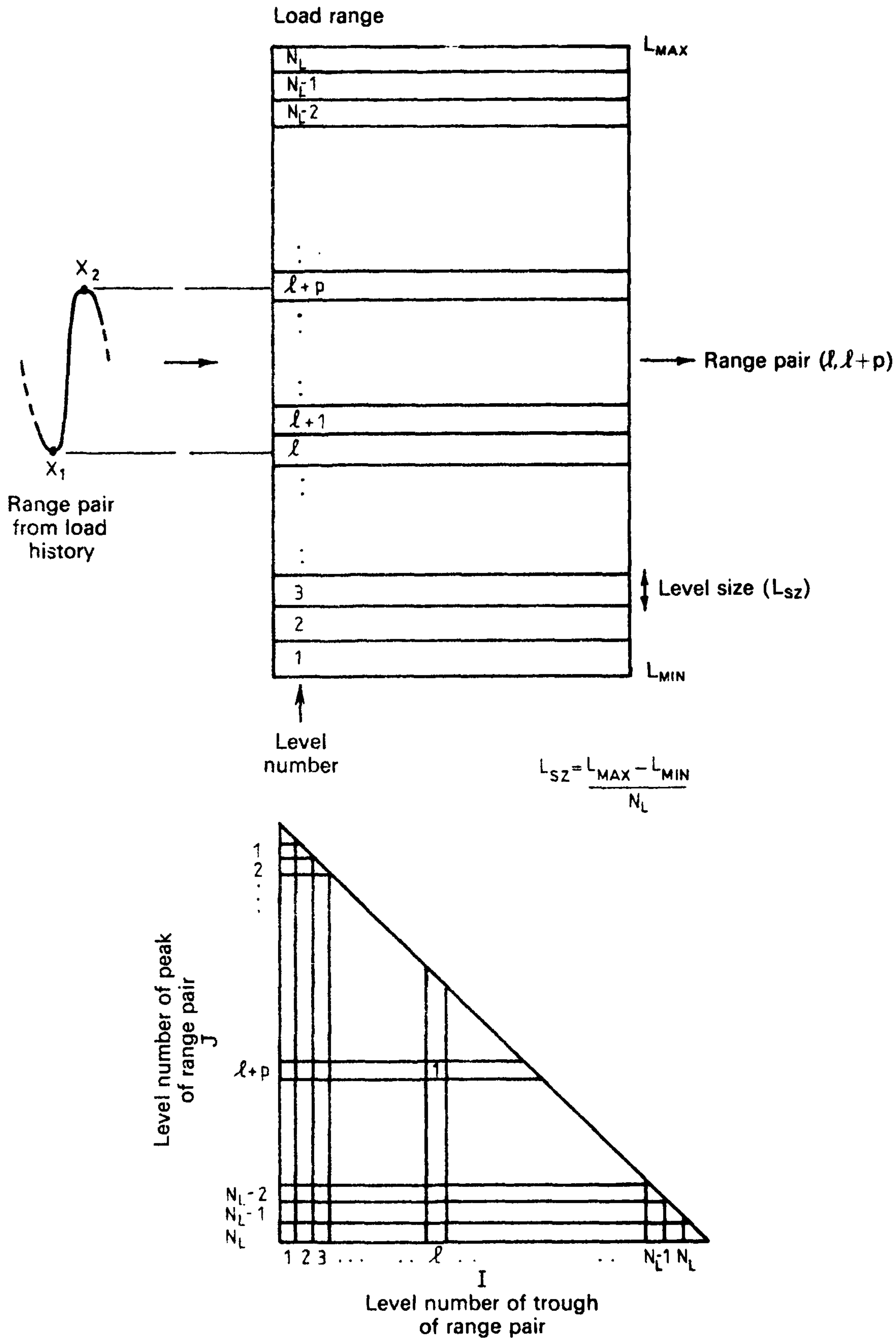
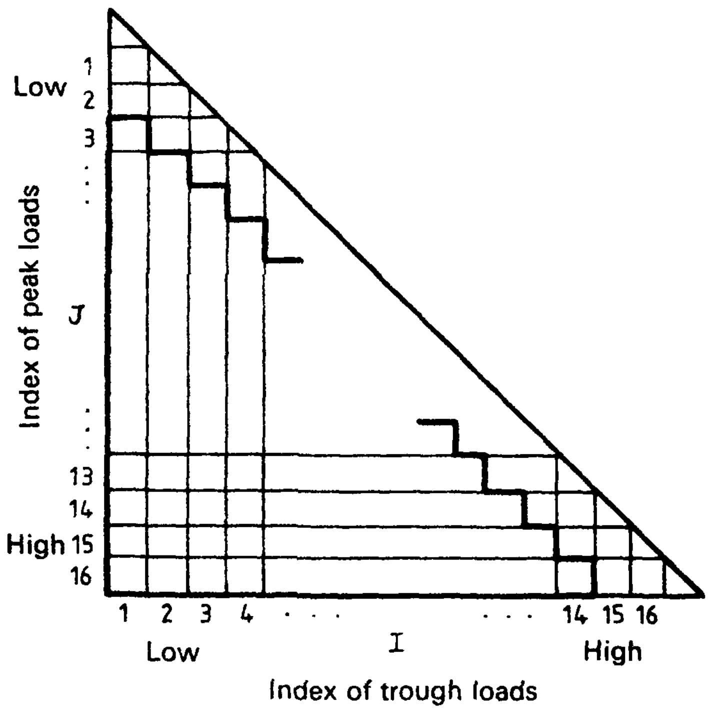


FIG. 3: THE REPRESENTATION OF A RANGE PAIR IN TABULAR FORM: THE RANGE PAIR TABLE

0															
0	0														
0	0	0													
0	0	600	0												
0	0	0	0	261											
0	0	0	52	484	3751										
0	0	0	36	5420	2747	920									
0	0	2	72	962	1906	339	446								
0	0	14	95	635	559	651	184	206							
0	0	30	73	484	425	161	321	100	68						
0	0	38	97	422	145	65	44	99	27	22					
0	0	48	92	181	41	10	11	5	28	10	0				
0	1	58	43	56	7	1	1	0	5	6	2	0			
0	2	35	18	8	2	0	0	0	0	0	3	1	0		
2	4	10	1	0	0	0	0	0	0	0	0	0	0	0	
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

FIG. 4: A TYPICAL RANGE PAIR TABLE OF 16 LEVELS



The strain range pair counter truncates the table that would be obtained using a 16-level load range by removing the two leading diagonals to produce the 14-level format outlined above

FIG. 5: THE STRAIN RANGE PAIR TABLE PRODUCED BY AFDAS

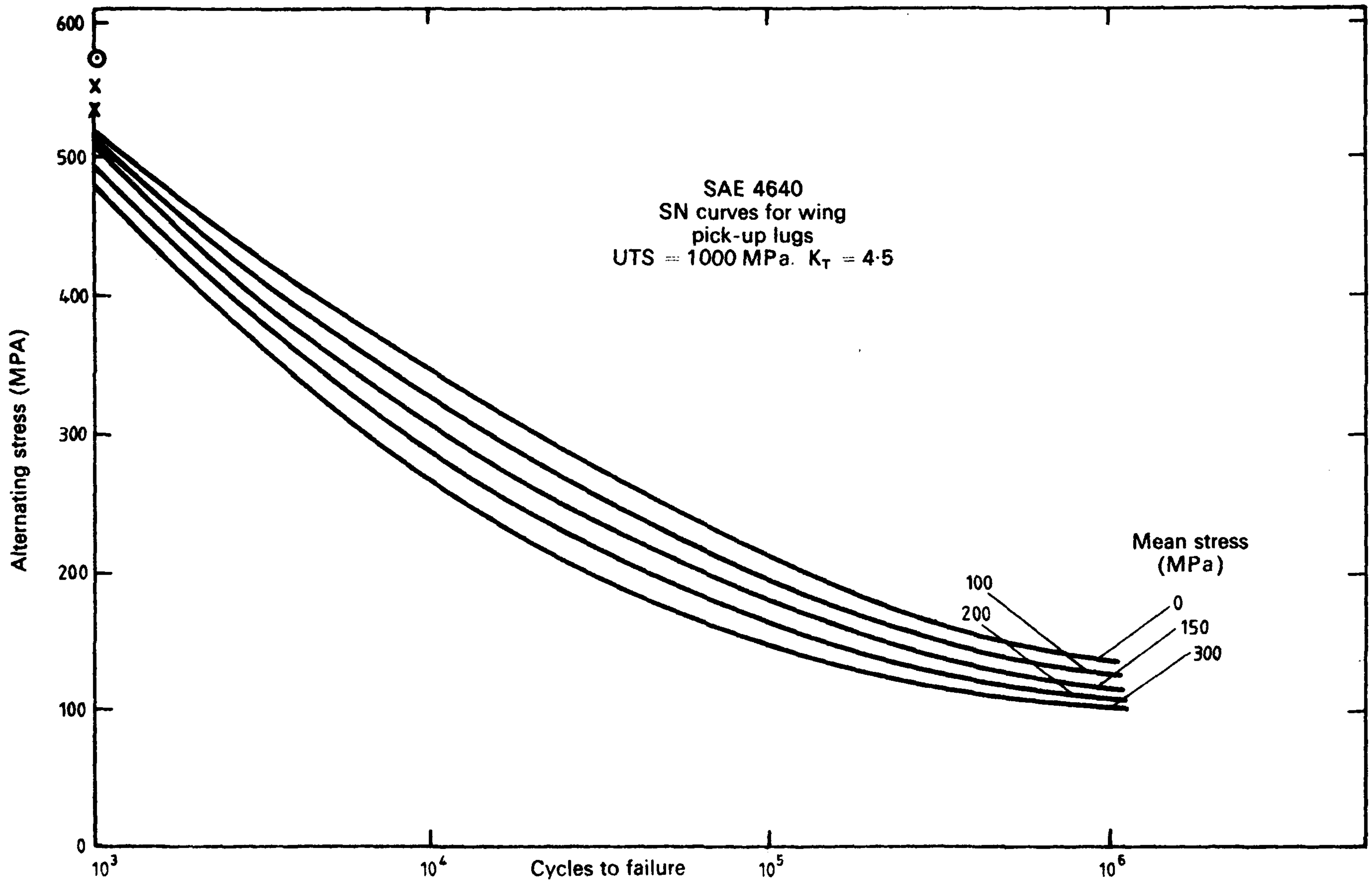


FIG. 6: TYPICAL S-N DATA

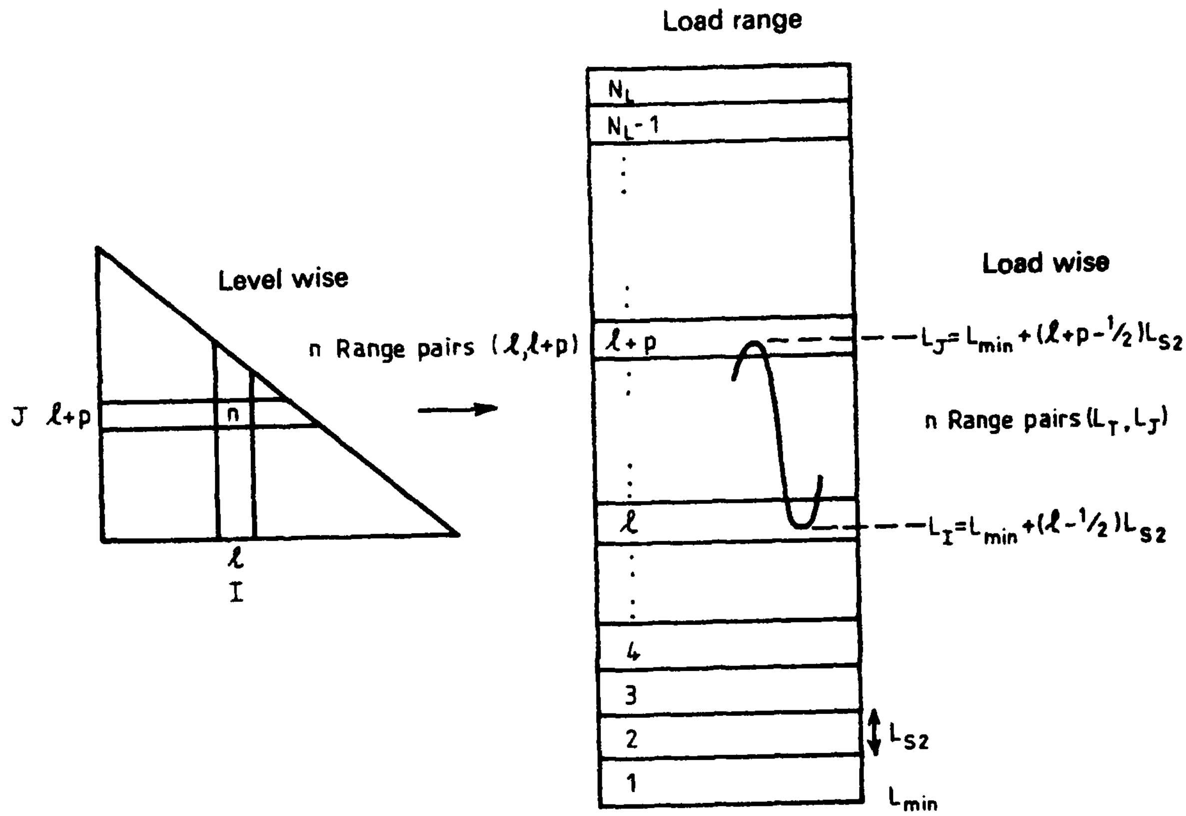


FIG. 7: LOAD DETERMINATION OF THE COUNTS IN THE RANGE PAIR TABLE

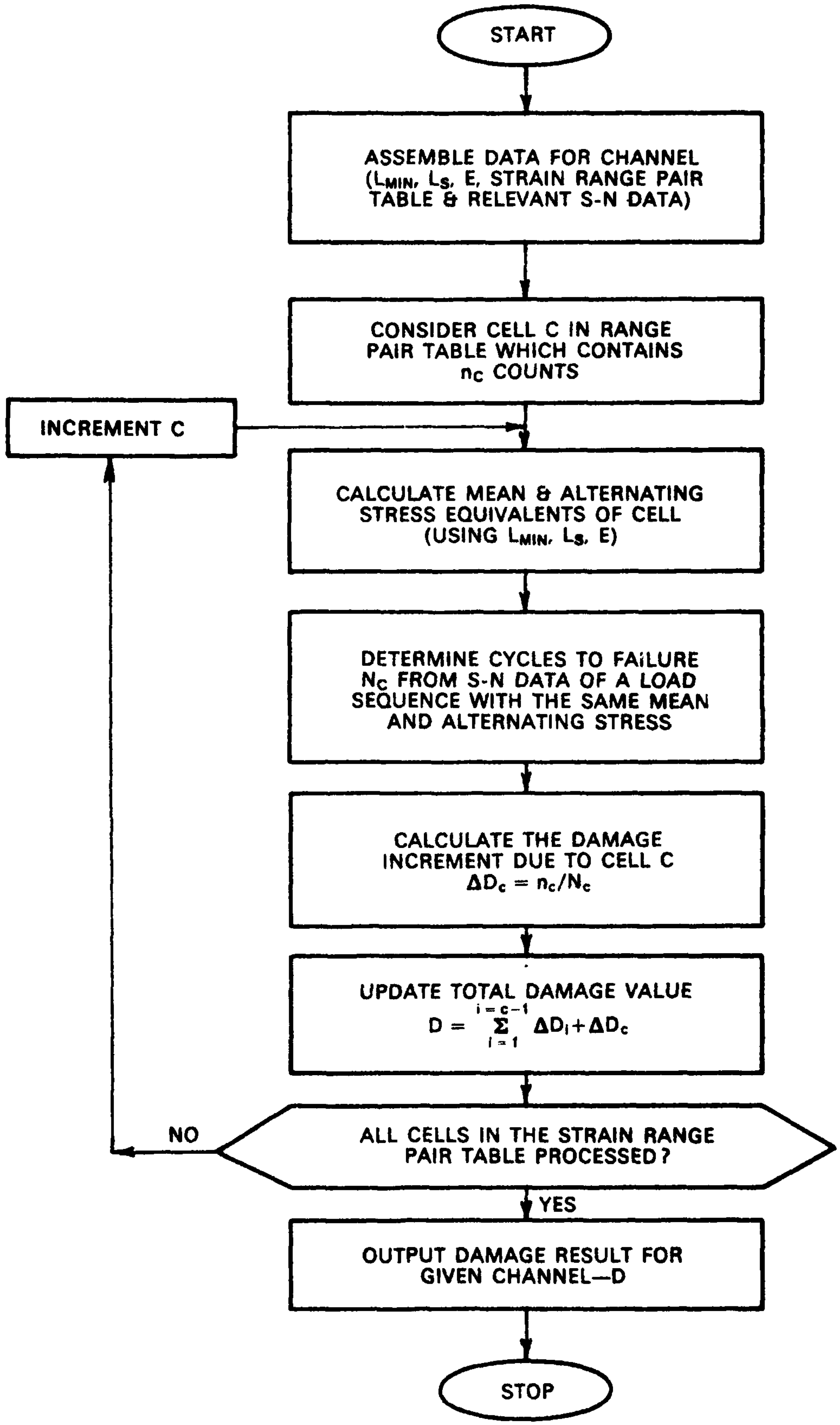


FIG. 8: LINEAR CUMULATIVE DAMAGE CALCULATION USING STRAIN RANGE PAIR DATA

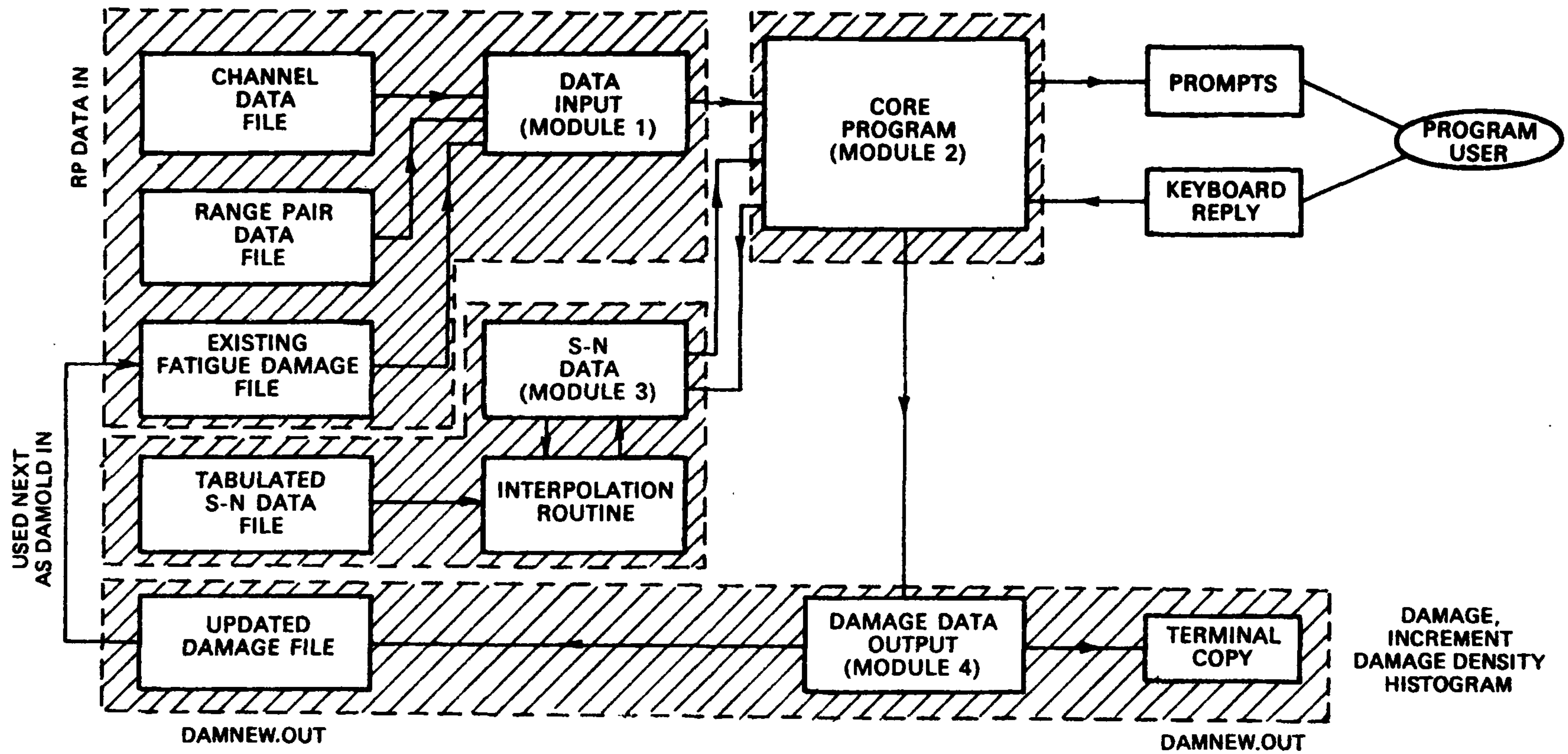
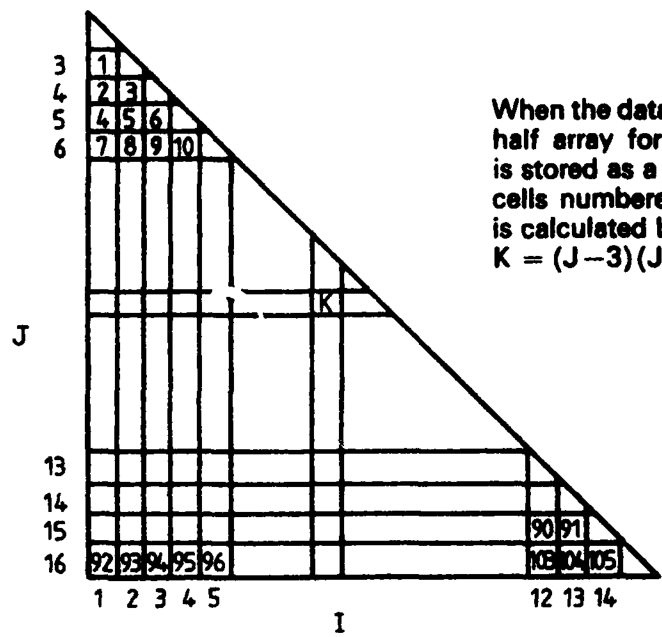


FIG. 9: THE STRUCTURE OF RPDAM WITHIN ITS OPERATING ENVIRONMENT



When the data of the 14-level half array format of AFDAS is stored as a vector with the cells numbered as shown, K is calculated by
$K = (J-3)(J-2)/2+I$

FIG. 10: VECTOR MANIPULATION OF RANGE PAIR DATA

APPENDIX

A computer program which implements the damage estimation procedure described earlier is documented in the following pages to allow this memo to serve as a user's manual and also as a reference for any program modifications desired. The program designated RPDAM (Range Pair Damage Analysis Method) is written in FORTRAN IV for the F10 or F40 compiler of the Digital Equipment Corporation DEC 10 computer system. It is considered however that the ideas, techniques and in most cases the particular sections of code involved are simple enough to be readily adapted for use on other computer systems.

1. GENERAL PROGRAM DESCRIPTION

RPDAM is a comparatively small program segmented into three Modules whose functions are respectively data input, general program management, the handling of S-N information and data output. It is designed to be run interactively from a computer terminal on a time sharing system and provides the user with the option of processing one or all of the strain channels monitored by the SRPC. Fig. 9 summarizes the program structure.

Program listings and sample runs are included at the end of this appendix and it is intended that they be consulted while reading the stepwise description of each program module that follows.

MODULE 1 (Input Data Program labelled DATAIN.F4)

1. The load data for each strain channel is read from a data file (CHDATA.IN) as a set of vectors called CL_{MIN},CL_{SZ},E (representing respectively L_{MIN},L_{SZ},E as before). The flags NSC and ISNF also read from the file identify respectively whether the relevant channel is used for monitoring strain and if so the set of S-N data to be used in the damage analysis of its strain range pair data.

2. Existing damage data for each strain channel is read from a data file. (This data file is the previous output file from RPDAM appropriately renamed DAMOLD.IN). This is required to determine the damage increment that has occured since range pair data for each channel was last processed and also to enable the updated damage file to be written in the event that not all the strain channels are processed. Thus the old damage value DAMOLD, the date of the SRPC data from which it was calculated, OLDTE, and the damage increment DAMINC since the date INGDTE are read into vectors for this purpose. The damage density data for all strain channels is similarly read from DAMOLD. (Since there are 14 alternating stress levels for each of eight channels the resulting vector is 112 units in length).

APPENDIX (CONTD.)

3. Range Pair Data is read from a data file (RPDATA.IN) only as it is required for each channel. (The contents of the SRPC memory are read onto a cassette tape by the IPDU and subsequently transferred by cassette reader to the data base of the computer system on which RPDAM is run). The range pair data for each channel is, when required, stored by the program as a vector of integer numbers, IRP, 105 units in length. (A 14 x 14 half array is comprised of 105 cells).

MODULE 2 (Core Program labelled RPDAM.F4)

1. Load and existing fatigue damage data is accessed via COMMON statements from the input program DATAIN.F4 (MODULE 1) as described above.

2. Flags enabling the program user to select output to the terminal, and single or complete channel processing are set.

3. Range pair data for the requested channel is accessed via a COMMON statement from DATAIN.

4. The procedure of Fig. 8 is implemented. Remembering that the range pair table from the SRPC is a 16 level table truncated to 14 levels as shown in Fig. 5, the program processes each cell of the current channel range pair table as defined by its peak level J (3-16) and by its trough level I (1-14). When the range pair table is stored in vector form as shown in Fig. 10 the equation that relates vector number K to the cell in the table defined by I and J is

$$K=((J-3)*(J-2))/2 + I$$

The damage increment of each cell in the table is determined by accessing the relevant S-N data of MODULE 3 using the mean and alternating stress equivalents of the cell. The damage contribution of the cell to the respective damage density stress level is also determined. When all the requested strain channels have been processed control is passed to MODULE 4 to write the updated damage file. When this is completed execution of the program ends.

MODULE 3 (SN Data Program labelled DAMAGE.F4)

This routine contains all the S-N data relevant to each of the eight possible structural locations monitored by the SRPC. The flag ISF, read from CHDATA by DATAIN defines the set of S-N data to be used for the current channel.

APPENDIX (CONTD.)

2. The mean and alternating stress equivalents of each cell in the range pair table being currently processed by RPDAM is used to determine from the required S-N data the cycles to failure (N) of one equivalent cycle. The damage value of this cycle ($10^6/N$ is the damage in microfails for the one cycle) returned to RPDAM and when multiplied by the number of range pair counts in the given cell gives the damage increment attributable to that cell.

3. The option exists for using S-N data that exists in either analytical or tabular form. When tabular S-N data is to be used the subroutines INTEP1,INTEP2 are used to interpolate between the data values to obtain N for the required mean and alternating stress. The interpolation method used is a form of Aitkens's Lagrangian method[10] the order of interpolation can be selected. Tabulated S-N data is contained in files designated TABL1.IN...TABLy.IN, where y takes the value of ISF. (e.g. if ISF=1,TABL1.IN is the data file read by INTEP1).

MODULE 4 (Data Output Program, labelled DAMOUT.F4)

1. The damage results for each channel are output to the user's terminal if this option has been requested.

2. The damage results for each channel are used to update the damage data read from DAMOLD by DATAIN. The damage output file DAMNEW.OUT containing the updated total damage values represented by the strain range pair table, the damage increment since last processing (i.e. since DAMOLD was obtained) and the damage density histograms for each channel are then written to disk. Program control then returns to RPDAM and execution ends.

2. PROGRAM OPERATION

A. INPUT DATA

The input data required by the program for the particular SRPC installation concerned is generated as follows:

(i) Strain range pair data contained in RPDATA.IN is obtained as previously mentioned by reading the magnetic tape cassette containing the memory contents of the SRPC. The file consists of eight separate sets of strain range pair data identified by aircraft number, date and channel number, and formatted as vectors whose elements number 1,2,....105 across the page - the element numbers correspond to that shown in Fig. 10 for representing a range pair table as a vector.

(ii) The load data (L_{min}, L_g, E) and strain and SN flags (NSC, ISNF) required to determine the load equivalents of the elements in each range pair table of strain, and subsequently the SN data to be used in the damage analysis, is contained in the file CHDATA.IN. This information is summarized in tabular form as shown in the example at the end of this appendix. The remainder of the file contains specific details about the input parameter to each channel of the SRPC (i.e. the nature of the transducer used, its location and any other information deemed necessary).

(iii) Old damage data required to determine the damage increment incurred since the last processing is simply the data output file of that run, DAMNEW.OUT renamed DAMOLD.IN The formatting and structure is thus the same as that for DAMNEW.OUT. (When the program is first run the DAMOLD used is a generated copy containing null values).

(iv) SN data to be used for each set of strain range pair data is identified by the flag ISNF in the data file CHDATA, and specified in DAMAGE.F4 if analytical in nature, or if in tabular form, in the data files TABL1.IN...TABLy.IN where y takes the value of ISNF for the relevant channel as mentioned.

The analytical SN data is expressed in DAMAGE, as shown in the sample listing, to determine in microfails the damage equivalent of one strain range pair cycle defined by the mean and alternating stress values SN and SA respectively.

The tabular SN data is formatted in TABLy.IN in terms of alternating stress against mean stress and the logarithm to base 10 of cycles to failure. The first two lines of the file specify the number of columns and rows of alternating stress, and the order of interpolation to be used for mean and alternating stress respectively. (These values should be greater than 1 and less than the number of rows and columns of alternating stress respectively). Subsequent rows contain the actual SN data formatted as shown below:

Mean Stress MPa	Logarithmic mean life (base 10)				
	3.0	3.3	9.7	...	6.7
0	510.1	423.8	376.7		137.3
100	502.3	408.1			
150	Alternating Stresses (MPa)				
200					
300	(see Fig. 6)				

The SN data contained in the table should encompass all the possible mean and alternating stress values to be found in a given table (these can be determined from L_{min},LS,E and the maximum alternating and mean strain values possible in the table: E*(15*LS) and E*(L_{min}+14.5*LS). If not, the interpolation programs INTEP1 and INTEP2 will use the minimum mean and alternating values provided and extrapolate linearly from the maximum values provided. Further the number of tabular points used should be maximized. Up to 20 points per mean stress curve are available and this capability should be utilized whenever possible. (The program INTEST.F4 is provided to drive INTEP1 and INTEP2 and test a given table for interpolation accuracy).

B. PROGRAM EXECUTION

Execution of the programs described will be computer system dependant, although generally similar to that for the DEC system 10 in the following:

1. Since, for a specific SRPC installation the source files RPDAM.F4,DATAIN.F4,DAMAGE.F4,DAMOUT.F4, and INTEP1.F4,INTEP2.F4 (if required) do not change it is advantageous to link and subsequently run them as a single object program (called RPDAM.EXE, a saved core image).

2. The data files (CHDATA.IN,RPDATA.IN,DAMOLD.F4,TABL1.IN,.... TABLy.IN) relevant to both the SRPC concerned and to the particular run involved (i.e. the correct RPDATA and DAMOLD files) are located on a retrievable storage device, (usually magnetic disk).

3. The object program RPDAM is run with the program user supplying yes,no (Y/N) answers to program prompts. Program execution will continue until all requested strain channels are processed. (Damage results in the same format as that used for the output file may be written to the program users terminal as they are obtained). The output data file is subsequently written (if requested) to the specified retrievable storage device (usually disk).

The execution of the program is demonstrated in the sample runs at the end of this appendix.

C. OUTPUT DATA

The damage data generated by RPDAM is presented in the output file DAMNEW.OUT. The load data (L_{min},LS,E), SN data flag ISNF, total damage value, damage increment since last processing and the damage density histogram for each strain channel are included according to the format specified by DAMOUT and demonstrated in the sample output in the next section. (If only selected strain channels have been processed the damage data for the other channels will be unchanged from DAMOLD).

PROGRAM LISTINGS FOLLOW:

IN ORDER

1. RPDAM.F4
2. DATAIN.F4
3. DAMAGE.F4
4. DAMOUT.F4
5. INTEP1.F4
6. INTEP2.F4
7. INTEST.F4

```
C
C
C****************************************************************
C
C MODULE 2 -- CORE PROGRAM RPDAM.F4
C
C               PURPOSE:
C                    FATIGUE DAMAGE ESTIMATION FROM STRAIN
C                    RANGE PAIR DATA OF THE AIRCRAFT FATIGUE
C                    DATA ANALYSIS SYSTEM.(AFDAS)
C
C               OTHER PROGRAMS REQUIRED:
C                  1.DATAIN.F4 -DATA INPUT ROUTINE(MODULE 1)
C                  2.DAMAGE.F4 -SN DATA ROUTINE   (MODULE 3)
C                  3.INTEP1.F4-        "              "
C                  4.INTEP2.F4-        "              "
C                  5.DAMOUT.F4 -DATA OUTPUT ROUTINE(MODULE 4)
C
C               DATA FILES REQUIRED:
C                  1.CHDATA.IN -LOAD PARAMETER FILE
C                  2.RPDATA.IN -RANGE PAIR DATA FILE(FROM SRPC)
C                  3.DAMOLD.IN -PREVIOUS OUTPUT FILE
C                  4.TABLEy.IN -TABULATED SN DATA FILE
C                              (y TAKES THE VALUE OF ISNF)
C
C               OUTPUT FILE PRODUCED:
C                  1.DAMNEW.OUT -UPDATED DAMAGE DATA
C
C               MAIN VARIABLES:
C                  1.CLMIN -BOTTOM LEVEL LOAD VALUE (I.E LMIN)
C                  2.CLSZ  -LOAD LEVEL SIZE (I.E LSZ)
C                  3.DAMINC-DAMAGE INCREMENT SINCE LAST
C                           PROCESSING OF CHANNEL
C                  4.DAMNEW-NEW DAMAGE VALUE FOR CHANNEL
C                  5.DAMOLD-OLD DAMAGE VALUE AT LAST
C                           PROCESSING FOR CHANNEL
C                  6.DDALL -DAMAGE DENSITY VALUES FOR
C                           ALL CHANNELS
C                  7.E     -YOUNG'S MODULUS
C                  8.IRP   -VECTOR OF STRAIN RANGE PAIRS
C                  9.ISNF  -FLAG INDENTIFYING SN DATA TO
C                           BE USED
C                 10.NSC   -FLAG INDENTIFYING STRAIN CHANNELS
C
C               REFERENCE: ARL TECH MEMO 297
C               WRITTEN 1/6/77.  R.C.FRASER GROUP 27 STRUCTURES
C                                DIVISION ARL.
C
C****************************************************************
C
      COMMON/A/CLMIN(8),E(8),CLSZ(8),NSC(8),ISNF(8),SDD(8)
      COMMON/B/OLDTE(16),DAMNEW(8),DAMOLD(8),NEWDTE(2),AIRNO(2),
     DDALL(112),DAMINC(8),INCDTE(16)
      COMMON/C/IRP(105)
      DIMENSION DD(14)
```

```
C
C                       GET DATA
      CALL DATAIN(0)
      TYPE 1100
      ACCEPT 600,STD
      TYPE 1200
      ACCEPT 600,UNDF
      TYPE 500
      ACCEPT 600,ANS1
      TYPE 1300
      IF(ANS1.EQ.'N')GOTO 20
C                       LOOP WHEN ALL CHANNELS REQUESTED
 10   ICH=ICH+1
      IF(ICH.GT.8)GOTO 70
      GOTO(10,30)NSC(ICH)+1
C                       LOOP WHEN SINGLE CHANNELS REQ'D
 20   TYPE 700
      ACCEPT 800,ICH
      IF(ICH.LT.1.OR.ICH.GT.8)GOTO 20
      GOTO(30)NSC(ICH)
      TYPE 900,ICH
      GOTO 20
C                       PROGRAM CORE
 30   CONTINUE
      CALL DATAIN(ICH)
      AE=E(ICH)
      ISF=ISMF(ICH)
      ALMIN=CLMIN(ICH)
      ALSZ=CLSZ(ICH)
      IFLAG=0
      DAM=0.0
      DO 35 L=1.14
      DD(L)=0.0
 35   CONTINUE
C                       PROCESS EVERY CELL OF RP TABLE
      DO 40 J=3.16
      K0=((J-3)*(J-2))/2
      DO 40 I=1.J-2
      K=K0+I
      IF(IRP(K).EQ.0)GOTO 40
C                       TROUGH AND PEAK MICROSTRAIN
      STRNI=ALMIN+ALSZ*(FLOAT(I)-0.5)
      STRNJ=ALMIN+ALSZ*(FLOAT(J)-0.5)
C                       MEAN AND ALT MICROSTRAIN
      STRNM=(STRNJ+STRNI)/2.0
      STRNA=(STRNJ-STRNI)/2.0
C                       MEAN AND ALT STRESS
      STRSM=STRNM*AE*1.E-6
      STRSA=STRNA*AE*1.E-6
C                       DAMAGE FOR CELL K
      IFLAG=IFLAG+1
      DELDAM=DAMAGE(ISF,STRSM,STRSA,IFLAG)*IRP(K)
      DAM=DAM+DELDAM
      DD(J-I-1)=DD(J-I-1)+DELDAM
 40   CONTINUE
C                       OUTPUT AND REZERO RESULTS
      DAMNEW(ICH)=DAM
      DAM=0.0
```

```
      DO 60 I=1,14
      NO=14*(ICH-1)
      DDALL(NO+I)=DD(I)
      DD(I)=0.0
 60   CONTINUE
      IF(STO.EQ.'Y')GOTO 50
      CALL DAMOUT(ICH)
 50   CONTINUE
      IF(ANS1.EQ.'Y')GOTO 10
      TYPE 1000
      ACCEPT 600.ANS2
      IF(ANS2.EQ.'Y')GOTO 20
 70   IF(WNDF.EQ.'N')GOTO 80
      CALL DAMOUT(0)
 80   CONTINUE
C
C
 500  FORMAT(' DAMAGE FOR ALL STRAIN CHANNELS REQ''D? (Y/N): '.$)
 600  FORMAT(2A5)
 700  FORMAT(' CHANNEL NO=? '.$)
 800  FORMAT(I3)
 900  FORMAT(' CHANNEL ',I3,' NOT USED FOR STRAIN')
 1000 FORMAT(' ANOTHER CHANNEL? (Y/N): '.$)
 1100 FORMAT(' SUPPRESS TTY OUTPUT? (Y/N): ',$)
 1200 FORMAT(' WRITE NEW DAMAGE FILE? (Y/N): ',$)
 1300 FORMAT(//)
      END
```

```
C
C
C*******************************************************************
C
C
C  MODULE 1 -- DATA INPUT PROGRAM DATAIN.F4
C
C               PURPOSE:
C                    DATA INPUT TO RPDAM FROM FILES CHDATA.IN
C                    RPDATA.IN AND DAMOLD.IN.
C
C               USE:
C                    DATAIN IS ACCESSED ONCE TO OBTAIN THE
C                    LOAD AND OLD DAMAGE DATA FOR ALL CHANNELS,
C                    AND THEN AS REQUIRED TO OBTAIN THE STRAIN
C                    RANGE PAIR DATA FOR A SPECIFIC CHANNEL.
C
C               COMMENTS:
C                    INPUT FILE SPECIFICATION IS FOR THE
C                    DEC-SYSTEM 10 (DIGITAL CORP.)
C
C*******************************************************************
C
      SUBROUTINE DATAIN(ICH)
      COMMON/A/CLMIN(8),E(8),CLSZ(8),NSC(8),ISNF(8),SDD(8)
      COMMON/B/OLDTE(16),DAMNEW(8),DAMOLD(8),NEWDTE(2),AIRNO(2),
     * DDALL(112),DAMINC(8),INCDTE(16)

      COMMON/C/IRP(105)
      DIMENSION WD(2),TEMP(14)
      GOTO(10)ICH+1
C                    READ RP DATA
      OPEN(UNIT=1,FILE='RPDATA.IN',ACCESS='SEQIN')
      ITEMP=7*ICH-1
      ENCODE(8,650,WD)ITEMP
      READ(1,WD)
      READ(1,600)IRP
      CLOSE(UNIT=1)
      RETURN
C               READ CHANNEL DATA
 10   CONTINUE
      OPEN(UNIT=1,FILE='CHDATA.IN',ACCESS='SEQIN')
      READ(1,620)
      DO 20 I=1,8
      READ(1,800)DUM,NSC(I),CLMIN(I),CLSZ(I),E(I),ISNF(I)
      SDD(I)=E(I)*CLSZ(I)*1.E-6
 20   CONTINUE
      CLOSE(UNIT=1)
C               READ OLD DAMAGE DATA
      OPEN(UNIT=1,FILE='DAMOLD.IN',ACCESS='SEQIN')
      READ(1,750)
      DO 50 I=1,8
      IF(NSC(I).EQ.1)GOTO 30
      READ(1,1100,END=50)
      GOTO 50
```

```
 30     READ(1,900,END=50)OLDTE(2*I-1),OLDTE(2*I),DAMOLD(I)
        READ(1,900)INCDTE(2*I-1),INCDTE(2*I),DAMINC(I)
        READ(1,1200)TEMP
        DO 40 J=1,14
        NO=14*(I-1)+J
        DDALL(NO)=TEMP(J)
 40     CONTINUE
        READ(1,700,END=50)
 50     CONTINUE
        CLOSE(UNIT=1)
C               PICK OFF CASSETTE DATE
        OPEN(UNIT=1,FILE='RPDATA.IN',ACCESS='SEQIN')
        READ(1,500)AIRNO,NEWDTE
        CLOSE(UNIT=1)
        RETURN
C
 500    FORMAT(2(17X,2A5,/))
 600    FORMAT(25I5)
 620    FORMAT(15(/))
 650    FORMAT('(',I3,'(/))')
 700    FORMAT(7(/))
 750    FORMAT(13(/))
 800    FORMAT(6G)
 900    FORMAT(17X.2A5.2X,F10.2)
 1100   FORMAT(13(/))
 1200   FORMAT(3(/),13X,14F7.1)
        END
```

```
C
C
C*****************************************************************
C
C MODULE 3 --SN DATA PROGRAM  DAMAGE.F4
C
C               PURPOSE:
C                    HANDLING OF SN DATA FOR THE CALCULATION
C                    OF FATIGUE DAMAGE FOR RANGE PAIR CYCLES
C
C               USE:
C                    DAMAGE.F4 IS ACCESSED FOR EVERY CELL IN
C                    THE STRAIN RANGE PAIR TABLE BEING
C                    CONSIDERED, TO DETERMINE THE DAMAGE
C                    EQUIVALENT OF ONE CYCLE FOR THAT CELL.
C
C               COMMENTS:
C                    THE SN DATA EXISTS IN TWO FORMS-
C                    1. ANALYTICAL FORM USED DIRECTLY
C                    2.TABULAR FORM FROM WHICH DATA
C                    IS OBTAINED USING AN INTERPOLATION
C                    PROCEDURE.-PROGRAMS INTEP1.F4,INTEP2.F4
C
C*******************************************************************
C
        FUNCTION DAMAGE(ISF,SM,SA,IFLAG)
C
        GOTO(100,200,300)ISF-1
C
C
C                       ISF=1:
C                       JOSTS'S SN DATA FOR
C                       AL STRUCTURES BASED ON
C                       HANGARTNER'S VERSION OF
C                       ESDU DATA SHEET E0201
        DATA A1,A2,A3,A4.A5/1.7678,3.7447,1.82607,
     *  13.5,6.20378/
        IF(SM.LT.0.0)SM=0.0
        TEMP=ALOG10(0.145038*SM+2.0)
        TEMP1=A4-A5*TEMP
        DENOM=A3-ALOG10(TEMP1)
        DENUM=A3-ALOG10(0.145038*SA)
        DIV=DENUM/DENOM
        IF(DIV.GT.2.1984)DIV=2.1894
        CYCLE=A1+A2*DIV
        DAMAGE=1.E6/10.0**CYCLE
        RETURN
C
C
C                       ISF=2:
C                       HEYWOOD"S SN DATA FOR AL
C                       BOLTED JOINTS-BEST JOINT
C                       CURVE
        DATA B1,B2/2.23E3,2.23/
 100    IF(SA.LT.2.235/0.145038)SA=2.235
        CYCLE=(B1/(0.145038*SA-B2))**2
        DAMAGE=1.E6/CYCLE
        RETURN
```

```
C
C
C
C                         ISF=3:
C                         SAE 4340 SN DATA FOR
C                         BOLTED JOINTS
      DATA C1,C2,C3,C4,C5,C6/39.23,0.2303,0.29,
     * 0.862, 2.7908,2.41513/
 200  IF(SM.LT.0.0)SM=0.0
      DENUM=SA-C1-SM/7.0
      IF(DENUM.LT.2.0)DENUM=2.0
      DENOM=SM/980.0
      DENOM=C2+C3*DENOM+C4*DENOM*DENOM
      DENUM=C5-ALOG10(DENUM)
      CYCLE=C6+DENUM/DENOM
      IF (CYCLE.GT.10.0)CYCLE=10.0
      DAMAGE=1.E6/10.0**CYCLE
      RETURN
C
C
C
C                         ISF=4:
C                         TABULATED SN DATA FOR
C                         D6AC STEEL, KT=4.0.
C                         (MACCHI SPAR)
 300  CONTINUE
      CALL INTEP1(SM,SA,ISF,IFLAG,CYCLE)
      DAMAGE=1.E6/10.0**CYCLE
      RETURN
C
C
C
      END
```

```
C
C***********************************************************************
C
C MODULE 4 --DATA OUTPUT PROGRAM DAMOUT.F4
C
C               PURPOSE:
C                    DAMAGE DATA OUTPUT TO TERMINAL IF
C                    IF REQUIRED, AND SUBSEQUENT
C                    UPDATE OF DAMAGE FILE DAMNEW.OUT
C
C               USE:
C                    DAMOUT.F4 IS ACTIVATED FROM RPDAM
C
C
C***************************************************************
C
      SUBROUTINE DAMOUT(ICH)
      COMMON/A/CLMIN(8),E(8),CLSZ(8),NSC(8),ISNF(8),SDD(8)
      COMMON/B/OLDTE(16),DAMNEW(8),DAMOLD(8),NEWDTE(2),AIRNO(2),
     * DDALL(112),DAMINC(8),INCDTE(16)
      DIMENSION DDS(14),DD(14)
C
      GOTO(20)ICH+1
C                    OUTPUT TO TTY
      TYPE 300,AIRNO,NEWDTE
      TYPE 500,ICH
      TYPE 600,CLMIN(ICH),CLSZ(ICH),E(ICH),ISNF(ICH)
      TYPE 700,NEWDTE,DAMNEW(ICH)
      DAMINC(ICH)=DAMNEW(ICH)-DAMOLD(ICH)
      TYPE 800,OLDTE(2*ICH-1),OLDTE(2*ICH),DAMINC(ICH)
      DO 10 J=1,14
      DDS(J)=FLOAT(J+1)/2.0*SDD(ICH)
      DD(J)=DDALL(14*(ICH-1)+J)
 10   CONTINUE
      TYPE 900,DDS
      TYPE 1000,DD
      RETURN
C                    OUTPUT TO FILE
 20   OPEN(UNIT=2,FILE='DAMNEW.OUT',ACCESS='SEQOUT')
      WRITE(2,200)
      WRITE(2,300)AIRNO,NEWDTE
      WRITE(2,400)
      DO 70 I=1,8
      WRITE(2,500)I
      IF(NSC(I).EQ.1)GOTO 30
      WRITE(2,1100)
      GOTO 70
 30   WRITE(2,600)CLMIN(I),CLSZ(I),E(I),ISNF(I)
      IF(DAMNEW(I).NE.0.0)GOTO 40
      WRITE(2,700)OLDTE(2*I-1),OLDTE(2*I),DAMOLD(I)
      WRITE(2,800)INCDTE(2*I-1),INCDTE(2*I),DAMINC(I)
      GOTO 50
 40   WRITE(2,700)NEWDTE,DAMNEW(I)
      DAMINC(I)=DAMNEW(I)-DAMOLD(I)
      WRITE(2,800)OLDTE(2*I-1),OLDTE(2*I),DAMINC(I)
 50   CONTINUE
```

```
      DO 60 J=1,14
      DDS(J)=FLOAT(J+1)/2.0*SDD(I)
      DD(J)=DDALL(14*(I-1)+J)
 60   CONTINUE
      WRITE(2,900)DDS
      WRITE(2,1000)DD
 70   CONTINUE
      RETURN
C
 200  FORMAT(/,' DAMAGE DATA FOR')
 300  FORMAT(' AIRCRAFT NUMBER ',2A5,/,
     *       ' DATE            ',2A5)
 400  FORMAT(4(/))
 500  FORMAT(' CHANNEL ',I3)
 600  FORMAT(' BOTTOM LEVEL    =',F8.2,' (MICROSTRAIN)',/,
     *       ' LEVEL SIZE      =',F8.2,'      "',/,
     *       ' YOUNG''S MODULUS=',E10.4,' (MEGAPASCAL)',/,
     *       ' SN DATA USED FLAGGED BY ISNF=',I3)
 700  FORMAT(' TOTAL DAMAGE TO ',2A5,' =',F10.2,
     *       ' (MICROFAILS)')
 800  FORMAT(' DAMAGE SINCE    ',2A5,' =',F10.2,
     *       '      "')
 900  FORMAT(' DAMAGE DENSITY HISTOGRAM:',/,
     *       ' ALTERNATING',/,
     *       ' STRESS (MPA)',14F8.1)
 1000 FORMAT(' DAMAGE (MF) ',14F8.1,///)
 1100 FORMAT(' NOT A STRAIN CHANNEL',12(/))
      END
```

```
C
C
C
C*************************************************
C
C  MODULE 3 --  INTERPOLATION PROGRAM INTEP1.F4
C
C               PURPOSE:
C                    INTERPOLATION BETWEEN VALUES
C                    OF N IN TABULAR FORM FOR
C                    REQUIRED MEAN AND ALT STRESS.
C
C               OTHER PROGRAMS REQUIRED:
C                    1.INTEP2.F4
C
C               DATA FILES REQUIRED:
C                    1.TABLv - TABULATED SN DATA
C                      (v TAKES THE VALUE OF ISNF)
C                       (MAX TABLE SIZE = 10R*20C)
C
C               COMMENTS:
C                   1.INTERPOLATION BETWEEN VALUES
C                    IN TABLE IS PERFORMED USING
C                    AITKEN'S LAGRANGIAN METHOD.
C                    (REF  ACTON,F.S 'NUMERICAL
C                    METHODS THAT WORK', HARPER
C                    & ROW 1970)
C                   2.THE ORDER OF INTERPOLATION
C                    FOR BOTH THE MEAN AND ALT STRESS
C                    VALUES IS SPECIFIED IN THE DATA
C                    FILE TABLv.IN
C                   3.TABULATED DATA SHOULD INCLUDE
C                    ALL POSSIBLE MEAN AND ALT STRESSES.
C                    IF NOT:
C                     (A)LINEAR EXTRAPOLATION IS
C                    USED WHEN MAX MEAN AND ALT
C                    STRESSES EXCEEDED.
C                     (B)THE MINIMUM MEAN AND ALT
C                    STRESSES USED WHEN INPUT VALUES
C                    ARE LOWER.
C
C************************************************************
C
      SUBROUTINE INTEP1(FM.FA.ISF.IFLAG.CYCLE)
      DIMENSION WD(2).SA(10.20).SM(10).SN(20).F(10).A(20)
C
      GOTO(10)IFLAG
      GOTO 30
C             READ TABLE
   10 CONTINUE
      SMIN=10000.0
      SMAX=0.0
      ENCODE(6.700.WD)ISF
      OPEN(UNIT=1.FILE=WD.ACCESS='SEQIN')
      READ(1.500)NOC.NOR
      READ(1.500)NO1.NO2
      READ(1.500)DUM.(SN(I).I=1.NOC)
```

```
      DO 20 I=1,NOR
      READ(1,600)SM(I),(SA(I,J),J=1,NOC)
      SMIN=AMIN1(SMIN,SM(I))
      SMAX=AMAX1(SMAX,SM(I))
 20   CONTINUE
      CLOSE(UNIT=1)
C             CHECK FOR MEAN OUT OF BOUNDS
 30   CONTINUE
      IF(FM.LT.SMIN)GOTO 50
      IF(FM.LE.SMAX)GOTO 60
      DO 40 J=1,NOC
      A(J)=SA(NOR,J)+(FM-SM(NOR))*(SA(NOR,J)-SA(NOR-1,J))
     * /(SM(NOR)-SM(NOR-1))
 40   CONTINUE
      GOTO 80
C
 50   FM=SMIN
C             INTERPOLATE BETWEEN MEANS
 60   CONTINUE
      DO 80 J=1,NOC
      DO 70 I=1,NOR
      F(I)=SA(I,J)
 70   CONTINUE
      A(J)=FUNC(FM,SM,F.NOR,NO1)
 80   CONTINUE
C             CHECK FOR ALT OUT OF BOUNDS
      IF(FA.LT.A(NOC))GOTO 90
      IF(FA.LE.A(1))GOTO 100
      CYCLE=SN(1)+(FA-A(1))*(SN(1)-SN(2))/(A(1)-A(2))
      RETURN
C
 90   FA=A(NOC)
C             INTERPOLATE BETWEEN NEW ALTS
 100  CYCLE=FUNC(FA,A,SN,NOC,NO2)
C
 500  FORMAT(2G)
 600  FORMAT(21G)
 700  FORMAT('TABL',I1,'.IN')
      END
```

```
C
C
C*****************************************************
C
C MODULE 3 -- INTERPOLATION PROGRAM INTEP2.F4
C
C               PURPOSE:
C                    INTERPOLATION BETWEEN VALUES OF
C                    A VECTOR USING AITKEN'S METHOD.
C
C               COMMENTS:
C                    ORDER OF INTERP FOR BOTH MEAN
C                    AND ALT VALUES CAN BE SPECIFIED.
C                    (SPECIFIED ON DATA FILE TABLy.IN)
C                    INTEP1 SUPPLIES TWO DATA VECTORS
C                    TO INTEP2: A,XAR WHERE A = f(XAR),
C                    AND A VALUE X FOR WHICH f(X)
C                    IS REQUIRED.
C
C*****************************************************
C
      FUNCTION FUNC(X,XAR,A,IMAX,NO1)
      DIMENSION XD(0/20),F(0/20),A(20),XAR(20)
      DATA IMIN,ARG/1,1.E-21/
C             CHECK ENOUGH DATA FOR ORDER
C             SPECIFIED
      IF(IMAX-IMIN.LT.NO1)NO1=IMAX-IMIN
      NO2=NO1/2
      IF(X.LT.XAR(1))GOTO 20
      DO 10 I=IMIN,IMAX-1
      IF(X.LE.XAR(I+1))GOTO 40
 10   CONTINUE
      I=IMAX
      GOTO 40
 20   DO 30 I=IMIN,IMAX-1
      IF(X.GE.XAR(I+1))GOTO 40
 30   CONTINUE
      I=IMIN
C
 40   IX=I
      IS=IX-NO2
      IF(IS.LT.IMIN)IS=IMIN
      IF(IS+NO1.GT.IMAX)IS=IMAX-NO1
      DO 50 J=0,NO1
      XD(J)=X-XAR(IS+J)
 50   F(J)=A(J+IS)
C             CALCULATE DIFFERENCES AND FUNCTIONAL
C             VALUES AROUND X
      DO 70 K=1,NO1
      KONS=0
      DO 60 J=0,NO1-K
      CONS=(F(J+1)-F(J))*XD(J)/(XD(J)-XD(J+K))
      IF(ABS(CONS).LT.ARG)KONS=KONS+1
 60   F(J)=F(J)+CONS
      IF(KONS.GE.NO1-K)GOTO 80
 70   CONTINUE
```

```
80    IA=IX-IS-K/2
      IF(IA.GT.N01-K)IA=N01-K
      IF(IA.LT.0)IA=0
      FUNC=F(IA)
      IF(ABS(FUNC).GT.1.0E15)FUNC=0.0
      RETURN
      END
```

```
C
C
C****************************************************************
C
C  INTEST.F4
C
C                PURPOSE:
C                     TO DRIVE INTEP1.F4 AND INTEP2.F4 FOR
C                     TESTING OF INTERPOLATION ACCURACY
C                     ON TABULAR SN DATA CONTAINED IN
C                     DATA FILE TABLy.IN.
C
C                COMMENTS:
C                     THE ACCURACY OF ANY INTERPOLATION
C                     METHOD DEPENDS HEAVILY ON THE
C                     NUMBER OF DATA POINTS PROVIDED.UP
C                     TO 20 DATA POINTS PER MEAN STRESS
C                     CURVE IS PROVIDED FOR
C                     INTEP1 AND THIS CAPABILITY SHOULD
C                     BE UTILIZED WHERE POSSIBLE.
C                     HOWEVER IT IS WISE TO ALWAYS CHECK THE
C                     EFFECT OF THE AMOUNT OF DATA PROVIDED
C                     AND THE ORDER OF INTERPOLATION FOR MEAN
C                     AND ALT STRESS USED, BY USING THIS
C                     PROGRAM TOGETHER WITH INTEP1.F4 AND
C                     INTEP2.F4 ON THE DATA FILE TABLy.IN .
C
C****************************************************************
C
      IFLAG=0
      TYPE 100
      ACCEPT 300.ISF
 10   TYPE 200
      ACCEPT 300.FM.FA
      IFLAG=IFLAG+1
      CALL INTEP1(FM.FA.ISF,IFLAG.CYCLE)
      AN=10.**CYCLE
      TYPE 400.FM.FA,AN
      TYPE 500
      ACCEPT 600.ANS
      IF(ANS.EQ.'Y')GOTO 10
100   FORMAT(' FOR INPUT FILE TABLv.IN v=? ',$)
200   FORMAT(' SM.SA FOR WHICH N DESIR''D=? '$)
300   FORMAT(2G)
400   FORMAT(' FOR SM,SA='2F10.4,' N=',E10.3//)
500   FORMAT(' ANOTHER? Y/N: '.$)
600   FORMAT(A5)
      END
```

DATA FILES FOR SAMPLE PROGRAM RUNS FOLLOW:
IN ORDER THEY ARE

1. CHDATA.IN
2. RPDATA.IN
3. DAMOLD.IN (EMPTY VERSION)
4. TABL4.IN

FILE CHDATA.IN************************************

LOAD DATA FILE FOR:
AIRCRAFT AAAAAXXXXX
BOTTOM LEVEL (LMIN) AND LEVEL SIZE
(LSZ) VALUES IN MICROSTRAIN (MS)
YOUNG'S MODULUS IN MEGAPASCAL(MPA)
THE FLAG ISNF SPECIFIES THE SN DATA SET TO
BE USED FOR EACH STRAIN CHANNEL.

SUMMARY:

CHANNEL	STRAIN	LMIN	CLSZ	E	ISNF
1	1	-500.0	135.00	170.00E3	1
2	1	-450.0	150.00	170.00E3	1
3	0	-3.0	0.75		
4	1	-200.0	250.00	170.00E3	3
5	0	-2.0	0.25		
6	1	-500.0	135.00	170.00E3	2
7	1	-1500.0	200.00	120.00E3	2
8	1	-1000.0	250.00	170.00E3	4

DETAIL:

CHANNEL 1
STRAIN GAUGE MOUNTED ON CENTRE SECTION
LOWER TENSION SPAR AT STATION 355 ONE
MM FROM REAR FLANGE EDGE.REFER DRAWING
NO 12/35/12-75

CHANNEL 2
STRAIN GAUGE MOUNTED ON SPAR CAP
PORTSIDE AT STATION 1255 3.5 MM FROM
FORWARD EDGE.

CHANNEL 3
OUTPUT FROM ACCELEROMETER MOUNTED IN
VERTICAL PLANE AT FUSELAGE STATION
1298.FULL SCALE SET AT -3.0 TO 9.0 G.

CHANNEL 4
STRAIN GAUGE MOUNTED ON FIN MAIN
SPAR AT ST 040

CHANNEL 5
OUTPUT FROM ACCELEROMETER MOUNTED IN
HORIZONTAL PLANE AT FUSELAGE STATION
1298.FULL SCALE SET AT -2.0 TO 2.0 G

CHANNEL 6
OUTPUT FROM STRAIN GAUGES 01/02/03
SUMMED LINEARLY ACCORDING TO EQUATION OF
TECH MEMO 253 TO GIVE STRAIN AT
CRITICAL BOLT HOLE NO 234.

CHANNEL 7
STARBOARD EQUIVALENT OF CHANNEL 2

CHANNEL 8
STARBOARD EQUIVALENT OF CHANNEL 1

FILE RPDATA.IN

```
[illegible] PART NUMBER AAAAANXXXX
DATE             00/00/00

CHANNEL 1
   0    0    0    0    0    0    0    0    0   52    0    0    0   36 5420    0    0    2   72  962 1906    0    0   14   95
 635  559  651    0    0   30   73  484  425  161  321    0    0   44   97  422  145   65   44   99    0   17   66   92  181
  41   10   32   36   28    0    8   51   43   56    7    1   23    9    5    6    3    2   29   18    8    2    0   16    0
   0    0    3    2    4    6    1    0    0    0    0    0    0    0    0    0    1    0    0    0    0    0    0    0    0
   0    0    0    0    0

CHANNEL 2
   0    0    0    0    0    0    0    0    0   52    0    0    0   36 5420    0    0    2   72  962 1906    0    0   14   95
 635  559  651    0    0   30   73  484  425  161  321    0    0   38   97  422  145   65   44   99    0    0   48   92  181
  41   10   11    5   28    0    1   58   43   56    7    1    1    0    5    6    0    2   35   18    8    2    0    0    0
   0    0    3    2    4   10    1    0    0    0    0    0    0    0    0    0    2    0    0    0    0    0    0    0    0
   0    0    0    0    0

CHANNEL 3
   0    0    0    0    0    2    0    0    1    2    0    0    0    1    0    0    1    0    2    0    0    0    0    0    1
   0    0    0    0    0    1    2    0    0    0    0    1    1    0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1   11   12    1    0    0    1    2    1
   0    0    0    0    0

CHANNEL 4
   0    0    0    0    0    0    0    0    0   52    0    0    5   36 5420    0    0   12   72  962 3906    0    0   14   95
 635  759  651    0    0   30   73  484  425  161  321    0    0   38   97  422  145   65   44   97    0    0   48   92  181
  41   10   11 [illegible] 28  0    1   58   43   56   37    1    1    0    5    6    0    2   35   18    8    2    5    0    0
   0    0    3    2    4   10    1    0    0    0    0    0    0    0    0    0    2    0    0    0    0    0    0    0    0
   0    0    0    0    0

CHANNEL 5
   0    0    1    0    0    0    0    0    1    3    0    0    0    0    1    0    0    0    2    0    0    0    0    0    1
   0    0    0    0    0    0    0    0    0    0    0    0    0    0    2    2    0    0    0    0    1    0    0    0    0
   0    0    0    0    0    1    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0   24    5    1    0    0    1    2
   0    0    0    0    0

CHANNEL 6
   0    0    0    0    0    0    0    0    0   52    0    0    0   36 5420    0    0    2   72  962 1906    0    0   14   95
 635  559  651    0    0   30   73  484  425  161  321    0    0   44   97  422  145   65   44   99    0   17   66   92  181
  41    0   32   36   28    0    8   51   43   56    7    1   23    9    5    6    3    2   29   18    8    2    0   16    0
   0    0    3    2    4    6    1    0    0    0    0    0    0    0    0    0    1    0    0    0    0    0    0    0    0
   0    0    0    0    0

CHANNEL 7
   0    0    0    0    0    0    0    0    0   52    0    0    0   36 5420    0    0    2   72  962 1906    0    0   14   95
 635  559  651    0    0   30   73  484  425  161  321    0    0   38   97  422  145   65   44   99    0    0   48   92  181
   4 [illegible] [illegible] [illegible] 28 0 1   58   43   56    7    1    1    0    5    6    0    2   35   18    8    2    0    0    0
   0    0 [illegible] 2    4   10    1    0    0    0    0    0    0    0    0    0    2    0    0    0    0    0    0    0    0
   0    0    0    0    0

CHANNEL 8
   0    0    0    0    0    0    0    0    0   52    0    0    5   36 5420    0    0   12   72  962 3906    0    0   14   95
 635  759  651    0    0   30   73  484  425  161  321    0    0   38   97  422  145   65   44   99    0    0   48   92  181
   4 [illegible] 11 [illegible] 28 0    1   58   43   56   37    1    1    0    5    6    0    2   35   18    8    2    5    0    0
   0    0    3    2    4   10    1    0    0    0    0    0    0    0    0    0    2    0    0    0    0    0    0    0    0
   0    0    0    0    0
```

DAMOLD.IN

```
DAMAGE DATA FOR
AIRCRAFT NUMBER AAAAAXXXXX
DATE            00/00/00



CHANNEL   1
BOTTOM LEVEL     =    0.00 (MICROSTRAIN)
LEVEL SIZE       =    0.00        "
YOUNG'S MODULUS=  0.00E+00  (MEGAPASCAL
SN DATA USED FLAGGED BY ISNF=  0
TOTAL DAMAGE TO 00/00/00   =       0.00   (MICROFAILS)
DAMAGE SINCE    00/00/00   =       0.00       "
DAMAGE DENSITY HISTOGRAM:
ALTERNATING
STRESS (MPA)     0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
DAMAGE (MF)      0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0


CHANNEL   2
BOTTOM LEVEL     =    0.00 (MICROSTRAIN)
LEVEL SIZE       =    0.00        "
YOUNG'S MODULUS=  0.00E+00  (MEGAPASCAL
SN DATA USED FLAGGED BY ISNF=  0
TOTAL DAMAGE TO 00/00/00   =       0.00   (MICROFAILS)
DAMAGE SINCE    00/00/00   =       0.00       "
DAMAGE DENSITY HISTOGRAM:
ALTERNATING
STRESS (MPA)     0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
DAMAGE (MF)      0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0


CHANNEL   3
BOTTOM LEVEL     =    0.00 (MICROSTRAIN)
LEVEL SIZE       =    0.00        "
YOUNG'S MODULUS=  0.00E+00  (MEGAPASCAL
SN DATA USED FLAGGED BY ISNF=  0
TOTAL DAMAGE TO 00/00/00   =       0.00   (MICROFAILS)
DAMAGE SINCE    00/00/00   =       0.00       "
DAMAGE DENSITY HISTOGRAM:
ALTERNATING
STRESS (MPA)     0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
DAMAGE (MF)      0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0


CHANNEL   4
BOTTOM LEVEL     =    0.00 (MICROSTRAIN)
LEVEL SIZE       =    0.00        "
YOUNG'S MODULUS=  0.00E+00  (MEGAPASCAL
SN DATA USED FLAGGED BY ISNF=  0
TOTAL DAMAGE TO 00/00/00   =       0.00   (MICROFAILS)
DAMAGE SINCE    00/00/00   =       0.00       "
DAMAGE DENSITY HISTOGRAM:
ALTERNATING
STRESS (MPA)     0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
DAMAGE (MF)      0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
```

CHANNEL 5
BOTTOM LEVEL = 0.00 (MICROSTRAIN)
LEVEL SIZE = 0.00 "
YOUNG'S MODULUS= 0.00E+00 (MEGAPASCAL
SN DATA USED FLAGGED BY ISNF= 0
TOTAL DAMAGE TO 00/00/00 = 0.00 (MICROFAILS)
DAMAGE SINCE 00/00/00 = 0.00 "
DAMAGE DENSITY HISTOGRAM:
ALTERNATING

STRESS (MPA)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DAMAGE (MF)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

CHANNEL 6
BOTTOM LEVEL = 0.00 (MICROSTRAIN)
LEVEL SIZE = 0.00 "
YOUNG'S MODULUS= 0.00E+00 (MEGAPASCAL
SN DATA USED FLAGGED BY ISNF= 0
TOTAL DAMAGE TO 00/00/00 = 0.00 (MICROFAILS)
DAMAGE SINCE 00/00/00 = 0.00 "
DAMAGE DENSITY HISTOGRAM:
ALTERNATING

STRESS (MPA)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DAMAGE (MF)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

CHANNEL 7
BOTTOM LEVEL = 0.00 (MICROSTRAIN)
LEVEL SIZE = 0.00 "
YOUNG'S MODULUS= 0.00E+00 (MEGAPASCAL
SN DATA USED FLAGGED BY ISNF= 0
TOTAL DAMAGE TO 00/00/00 = 0.00 (MICROFAILS)
DAMAGE SINCE 00/00/00 = 0.00 "
DAMAGE DENSITY HISTOGRAM:
ALTERNATING

STRESS (MPA)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DAMAGE (MF)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

CHANNEL 8
BOTTOM LEVEL = 0.00 (MICROSTRAIN)
LEVEL SIZE = 0.00 "
YOUNG'S MODULUS= 0.00E+00 (MEGAPASCAL
SN DATA USED FLAGGED BY ISNF= 0
TOTAL DAMAGE TO 00/00/00 = 0.00 (MICROFAILS)
DAMAGE SINCE 00/00/00 = 0.00 "
DAMAGE DENSITY HISTOGRAM:
ALTERNATING

STRESS (MPA)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DAMAGE (MF)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[illegible] NO OF DATA COLUMNS AND ROWS

[illegible] INTERPOLATION ORDERS FOR SM, SA

[illegible]	3.0	3.3	3.7	4.0	4.3	4.7	5.0	5.3	5.7	6.0	6.7
[illegible].00	51[illegible]	423.8	376.7	343.4	278.6	241.3	215.8	171.7	154.5	146.2	137.3
100.00	502.[illegible]	408.[illegible]	358.1	323.7	259.0	223.7	200.1	159.7	144.7	135.9	127.5
150.00	490.3	392.[illegible]	341.4	304.1	240.3	206.0	185.4	147.2	132.4	125.6	117.7
200.00	480.7	370.7	32[illegible].8	284.5	221.7	189.3	169.7	136.4	124.6	117.7	112.8
300.00	470.7	361.0	302.1	254.7	201.1	171.7	154.0	125.6	115.3	111.8	107.9

```
SAMPLE PROGRAM RUN:
(DAMOLD.IN USED IS  EMPTY)

.EX RPDAM.F4,DATAIN.F4.DAMAGE.F4,DAMOUT.F4,INTEP1.F4,INTEP2.F4

FORTRAN:  RPDAM.F4
FORTRAN:  DATAIN.F4
FORTRAN:  DAMAGE.F4
FORTRAN:  DAMOUT.F4
FORTRAN:  INTEP1.F4
FORTRAN:  INTEP2.F4
LOADING

RPDAM 4K CORE
EXECUTION

SUPPRESS TTY OUTPUT? (Y/N): Y
WRITE NEW DAMAGE FILE? (Y/N): Y
DAMAGE FOR ALL STRAIN CHANNELS REQ'D? (Y/N): Y



END OF EXECUTION
CPU TIME: 3.47  ELAPSED TIME: 23.38
EXIT
```

THE DAMNEW.OUT PRODUCED FOR THIS FIRST RUN FOLLOWS:

```
DAMAGE DATA FOR
AIRCRAFT NUMBER AAAAAXXXXX
DATE            01/01/78



CHANNEL   1
BOTTOM LEVEL     = -500.00 (MICROSTRAIN)
LEVEL SIZE       =  135.00        "
YOUNG'S MODULUS= .1700E+06 (MEGAPASCAL)
SN DATA USED FLAGGED BY ISNF=  1
TOTAL DAMAGE TO 01/01/78    =  70309.86 (MICROFAILS)
DAMAGE SINCE    00/00/00    =  70309.86      "
DAMAGE DENSITY HISTOGRAM:
ALTERNATING
STRESS (MPA)    23.0    34.4    45.9    57.4    68.7    80.3    91.8   103.3   114.8   126.2   137.7   149.2   160.6   172.1
DAMAGE (MF)   1310.1  1740.8  4013.5  5951.0  9487.9  9317.2  9446.0  8570.5  9251.0  6121.9  1891.5  1974.1   730.5   503.8


CHANNEL   2
BOTTOM LEVEL     = -450.00 (MICROSTRAIN)
LEVEL SIZE       =  150.00        "
YOUNG'S MODULUS= .1700E+06 (MEGAPASCAL)
SN DATA USED FLAGGED BY ISNF=  1
TOTAL DAMAGE TO 01/01/78    = 129064.38 (MICROFAILS)
DAMAGE SINCE    00/00/00    = 129064.38      "
DAMAGE DENSITY HISTOGRAM:
ALTERNATING
STRESS (MPA)    25.5    38.3    51.0    63.8    76.5    89.3   102.0   114.8   127.5   140.3   153.0   165.8   178.5   191.3
DAMAGE (MF)   3386.0  3815.8  8174.4 11517.1 17648.2 17783.1 17181.7 13540.7 15327.7 10700.7  4917.0  2061.9  1249.5  1680.6


CHANNEL   3
NOT A STRAIN CHANNEL



CHANNEL   4
BOTTOM LEVEL     = -200.00 (MICROSTRAIN)
LEVEL SIZE       =  250.00        "
YOUNG'S MODULUS= .1700E+06 (MEGAPASCAL)
SN DATA USED FLAGGED BY ISNF=  3
TOTAL DAMAGE TO 01/01/78    =  32955.59 (MICROFAILS)
DAMAGE SINCE    00/00/00    =  32955.59      "
DAMAGE DENSITY HISTOGRAM:
ALTERNATING
STRESS (MPA)    42.5    63.8    85.0   106.3   127.5   148.8   170.0   191.3   212.5   233.8   255.0   276.3   297.5   318.8
DAMAGE (MF)      0.7     2.1    42.0   773.2  2770.1  4988.4  5245.4  4718.8  5830.9  4375.0  2095.7   872.5   520.0   712.7
```

CHANNEL 5
NOT A STRAIN CHANNEL

CHANNEL 6
BOTTOM LEVEL = -500.00 (MICROSTRAIN)
LEVEL SIZE = 135.00 "
YOUNG'S MODULUS= .1700E+06 (MEGAPASCAL)
SN DATA USED FLAGGED BY ISNF= 2
TOTAL DAMAGE TO 01/01/78 = 43353.96 (MICROFAILS)
DAMAGE SINCE 00/00/00 = 43353.96 "
DAMAGE DENSITY HISTOGRAM:
ALTERNATING

STRESS (MPA)	23.0	34.4	45.9	57.4	68.9	80.3	91.8	103.3	114.8	126.2	137.7	149.2	160.6	172.1
DAMAGE (MF)	2059.6	2767.7	4879.5	5663.5	6858.6	5621.1	4793.2	3824.0	3592.6	1975.2	506.4	530.1	178.6	103.9

CHANNEL 7
BOTTOM LEVEL =-1500.00 (MICROSTRAIN)
LEVEL SIZE = 200.00 "
YOUNG'S MODULUS= .1200E+06 (MEGAPASCAL)
SN DATA USED FLAGGED BY ISNF= 2
TOTAL DAMAGE TO 01/01/78 = 47265.68 (MICROFAILS)
DAMAGE SINCE 00/00/00 = 47265.68 "
DAMAGE DENSITY HISTOGRAM:
ALTERNATING

STRESS (MPA)	24.0	36.0	48.0	60.0	72.0	84.0	96.0	108.0	120.0	132.0	144.0	156.0	168.0	180.0
DAMAGE (MF)	2670.2	3188.6	5430.9	6208.3	7473.4	6275.2	5169.5	3592.9	3519.1	2128.8	839.8	334.6	197.1	229.3

CHANNEL 8
BOTTOM LEVEL =-1000.00 (MICROSTRAIN)
LEVEL SIZE = 250.00 "
YOUNG'S MODULUS= .1700E+06 (MEGAPASCAL)
SN DATA USED FLAGGED BY ISNF= 4
TOTAL DAMAGE TO 01/01/78 = 13354.88 (MICROFAILS)
DAMAGE SINCE 00/00/00 = 13354.88 "
DAMAGE DENSITY HISTOGRAM.
ALTERNATING

STRESS (MPA)	42.5	63.8	85.0	106.3	127.5	148.8	170.0	191.3	212.5	233.8	255.0	276.3	297.5	318.8
DAMAGE (MF)	2092.2	393.5	242.0	149.0	624.5	1683.0	1395.8	1314.7	2062.4	1855.2	758.3	301.7	179.4	303.2

At this point it needs to be remembered that the program DAMAGE.F4 (Sh data) and the input and output files ..DATA.IN,DAMOLD.IN,RPDATA.IN.DAMNEW.OUT are SRPC installation dependent and for the last three also run dependent. Hence an accounting system must be used to keep track of them. (this is left to the discretion of the user.)

SAMPLE PROGRAM RUN:

RPDATA.IN ... this run is an updated version of that used pr... usly. Hence DAMOLD.IN is the renamed output file f.. the previous run.

The programs RPDAM.F4 ... INTEP2.F4 have been joined together as a single program called RPDAM1.F4 which has been compiled and subsequently loaded.The core image resulting has been saved and it is this **EXE** version which is used in the following sample runs.

```
RU   .DAM1

SUPPRESS ... OUTPUT? (Y/N): Y
WRITE NEW DAMAGE FILE? (Y/N): Y
DAMAGE FOR ALL STRAIN CHANNELS REQ'D? (Y/N): Y

END OF EXECUTION
CPU TIME: 3.39  ELAPSED TIME: 20.20
EXIT
```

The range pair data file (RPDATA.IN) and the damage output file (DAMNEW.OUT) for this run follow:

AIRCRAFT NUMBER AAAAAXXXX
DATE 02/01/78

CHANNEL 1

0	0	0	0	0	0	0	0	0	60	0	0	0	76	6220	0	0	2	72	962	1906	0	0	14	95
825	893	748	0	0	45	93	675	425	254	321	0	0	56	97	486	145	65	44	99	0	17	66	72	181
78	54	32	36	28	0	8	51	43	56	7	1	23	9	5	6	3	2	45	26	15	2	0	16	0
0	0	3	2	9	7	4	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
0	0	0	0	0																				

CHANNEL 2

0	0	0	0	0	0	0	0	0	71	0	0	0	67	6420	0	0	8	83	962	1906	0	0	14	95
635	559	651	0	0	58	83	484	682	161	321	0	0	53	97	422	268	65	44	99	0	0	48	92	181
41	25	43	9	28	0	1	58	43	74	7	1	1	0	5	6	0	12	35	35	178	2	0	0	0
0	0	3	5	6	16	1	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
0	0	0	0	0																				

CHANNEL 3

0	0	0	0	0	2	0	0	1	7	0	0	0	2	0	0	1	0	3	0	0	0	0	0	1
0	0	0	0	0	1	4	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	11	12	1	0	0	1	2	1
0	0	0	0	0																				

CHANNEL 4

0	0	0	0	0	0	0	0	0	594	0	26	5	79	6682	0	0	66	72	962	3906	0	0	14	95
735	559	951	0	0	77	63	784	425	161	321	0	0	38	97	422	145	65	44	99	0	0	48	92	181
41	10	11	5	28	0	1	58	43	56	37	1	1	0	5	6	0	2	35	18	8	2	5	0	0
0	0	0	2	4	10	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
0	0	0	0	0																				

CHANNEL 5

0	0	1	0	0	0	0	0	1	3	0	0	0	0	2	0	0	0	4	0	0	0	0	0	1
1	0	0	0	1	0	0	0	0	0	0	0	0	0	4	2	0	0	0	0	1	0	0	0	0
0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	5	1	0	0	1	2
0	0	0	0	0																				

CHANNEL 6

0	0	0	0	0	0	0	0	0	88	0	0	8	58	5720	0	0	9	798	962	2906	0	0	75	95
635	557	607	0	0	30	73	484	425	161	321	0	0	44	97	422	145	65	44	99	0	17	66	72	181
41	10	32	36	28	0	8	51	43	56	7	1	23	9	5	6	3	2	29	18	8	2	0	16	0
0	0	3	2	4	6	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
0	0	0	0	0																				

CHANNEL 7

0	0	0	0	0	0	0	0	0	52	0	0	0	36	5420	0	0	2	85	1156	2666	0	0	88	95
635	559	651	0	0	30	73	484	425	161	321	0	0	38	97	422	145	65	44	99	0	0	48	92	181
41	10	11	5	28	0	1	77	63	57	7	6	1	0	5	6	3	8	82	38	8	2	0	0	0
0	0	2	7	5	13	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
0	0	0	0	0																				

CHANNEL 8

0	0	0	0	0	0	0	0	0	53	0	0	7	39	5428	0	0	18	82	981	4206	0	0	14	95
545	[illegible]	[illegible]	0	0	55	77	584	425	251	521	0	0	35	98	446	235	65	44	99	0	0	48	72	181
41	10	1	5	28	0	1	58	43	56	37	1	1	0	5	6	0	2	35	18	8	2	5	0	0
0	0	0	2	4	10	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
0	0	0	0	0																				

DAMAGE DATA FOR
AIRCRAFT NUMBER AAAAAXXXXX
DATE 02/01/78

CHANNEL 1
BOTTOM LEVEL = -500.00 (MICROSTRAIN)
LEVEL SIZE = 135.00 "
YOUNG S MODULUS= .1700E+06 (MEGAPASCAL)
SN DATA USED FLAGGED BY ISNF= 1
TOTAL DAMAGE TO 02/01/78 = 84023.32 (MICROFAILS)
DAMAGE SINCE 01/01/78 = 13713.46 "
DAMAGE DENSITY HISTOGRAM.
ALTERNATING

STRESS (MPA)	23.0	34.4	45.9	57.4	68.9	80.3	91.8	103.3	114.8	126.2	137.7	149.2	160.6	172.1
DAMAGE (MF)	1476.4	2268.5	4505.0	7914.7	11602.1	9590.2	9881.0	9257.2	10289.1	9374.2	2137.3	3485.8	730.5	1511.3

CHANNEL 2
BOTTOM LEVEL = -450.00 (MICROSTRAIN)
LEVEL SIZE = 150.00 "
YOUNG S MODULUS= .1700E+06 (MEGAPASCAL)
SN DATA USED FLAGGED BY ISNF= 1
TOTAL DAMAGE TO 02/01/78 = 182128.76 (MICROFAILS)
DAMAGE SINCE 01/01/78 = 33062.50 "
DAMAGE DENSITY HISTOGRAM.
ALTERNATING

STRESS (MPA)	25.5	38.3	51.0	63.8	76.5	89.3	102.0	114.8	127.5	140.3	153.0	165.8	178.5	191.3
DAMAGE (MF)	3661.3	5869.0	10723.1	14358.0	17879.7	18850.5	20185.0	42791.9	19187.4	10780.7	11083.0	3092.9	3123.7	2520.8

CHANNEL 3
NOT A STRAIN CHANNEL

CHANNEL 4
BOTTOM LEVEL = 200.00 (MICROSTRAIN)
LEVEL SIZE = 25[illegible] "
YOUNG S MODULUS= [illegible] (MEGAPASCAL)
SN DATA USED FLAGGED BY ISNF= [illegible]
TOTAL DAMAGE TO [illegible] = [illegible] (MICROFAILS)
DAMAGE SINCE [illegible]78 = 492.35 "
DAMAGE DENSITY HISTOGRAM.
ALTERNATING

STRESS (MPA)	42.5	63.8	85.0	106.3	127.5	148.8	170.0	191.3	212.5	233.8	255.0	276.3	297.5	[illegible]
DAMAGE (MF)	9.3	[illegible]	46.6	1133.3	2809.2	5066.2	5245.4	4718.0	[illegible]	4375.0	[illegible]	[illegible]	520.0	[illegible]

CHANNEL 5
NOT A STRAIN CHANNEL

CHANNEL 6
BOTTOM LEVEL = -500.00 (MICROSTRAIN)
LEVEL SIZE = 135.00 "
YOUNG'S MODULUS= .1700E+06 (MEGAPASCAL)
SN DATA USED FLAGGED BY ISNF= 2
TOTAL DAMAGE TO 02/01/78 = 47395.13 (MICROFAILS)
DAMAGE SINCE 01/01/78 = 4041.17 "
DAMAGE DENSITY HISTOGRAM:
ALTERNATING

STRESS (MPA)	23.0	34.4	45.7	57.4	68.9	80.3	91.8	103.3	114.8	126.2	137.7	149.2	160.6	172.[illegible]
DAMAGE (MF)	[illegible]	2601.5	7772.6	5715.9	7596.4	5621.1	4793.2	3824.0	3592.6	1975.2	506.4	530.1	178.6	103.9

CHANNEL 7
BOTTOM LEVEL = -1500.00 (MICROSTRAIN)
LEVEL SIZE = 200.00 "
YOUNG'S MODULUS= .1200E+06 (MEGAPASCAL)
SN DATA USED FLAGGED BY ISNF= 2
TOTAL DAMAGE TO 02/01/78 = 55891.01 (MICROFAILS)
DAMAGE SINCE 01/01/78 = 8626.23 "
DAMAGE DENSITY HISTOGRAM:
ALTERNATING

STRESS (MPA)	24.0	36.0	48.0	60.0	72.0	84.0	96.0	108.0	120.0	132.0	144.0	156.0	168.0	180.0
DAMAGE (MF)	2907.4	3537.6	5497.5	6208.3	8544.9	6315.0	5252.0	4318.7	5417.6	4933.0	1467.7	669.2	639.8	[illegible]

CHANNEL 8
BOTTOM LEVEL = -1000.00 (MICROSTRAIN)
LEVEL SIZE = 250.00 "
YOUNG'S MODULUS= .1700E+06 (MEGAPASCAL)
SN DATA USED FLAGGED BY ISNF= 4
TOTAL DAMAGE TO 02/01/78 = 13558.56 (MICROFAILS)
DAMAGE SINCE 01/01/78 = 203.66 "
DAMAGE DENSITY HISTOGRAM:
ALTERNATING

STRESS (MPA)	42.5	63.8	95.0	106.3	127.5	148.8	170.0	191.3	212.5	233.8	255.0	276.3	297.5	318.[illegible]
DAMAGE (MF)	[illegible]	418.6	246.4	168.2	654.1	1697.8	1378.6	1314.7	2062.4	1855.2	758.3	301.7	179.4	[illegible]

SAMPLE RUN:

Using the same input data as for the previous run the following results are obtained when using the options available.

```
.RU RPDAM1



SUPPRESS TTY OUTPUT? (Y/N): N
WRITE NEW DAMAGE FILE? (Y/N): N
DAMAGE FOR ALL STRAIN CHANNELS REQ'D? (Y/N): N


CHANNEL NO.? 1
AIRCRAFT NUMBER AAAAAXXXXX
DATE            02/01/78
CHANNEL    1
BOTTOM LEVEL     =  300.00 (MICROSTRAIN)
LEVEL SIZE       =  135.00      "
YOUNG'S MODULUS= .7300E+06 (MEGAPASCAL)
ON DATA USED FLAGGED BY ISNF=  1
TOTAL DAMAGE TO 02/01/78    =  34023.32 (MICROFAILS)
DAMAGE SINCE    01/01/78    =  13713.46      "
DAMAGE DENSITY HISTOGRAM:
ALTERNATING
STRESS (MPA)     23.0    34.4    45.9    57.4    68.9    80.3    91.8   103.3   114.8   126.2   137.7   149.2   160.6   172.1
DAMAGE (MF)    1476.4  2268.5  4505.0  7914.7 11602.1  7590.2  9881.0  9257.2 10289.1  9374.2  2137.3  3465.3   730.5  1511.3


ANOTHER CHANNEL? (Y/N): Y
CHANNEL NO.? 8
AIRCRAFT NUMBER AAAAAXXXXX
DATE            02/01/78
CHANNEL    8
BOTTOM LEVEL     = 1000.00 (MICROSTRAIN)
LEVEL SIZE       =  250.00      "
YOUNG'S MODULUS= .1700E+06 (MEGAPASCAL)
ON DATA USED FLAGGED BY ISNF=  4
TOTAL DAMAGE TO 02/01/78    =  13558.05 (MICROFAILS)
DAMAGE SINCE    01/01/78    =    203.68      "
DAMAGE DENSITY HISTOGRAM:
ALTERNATING
STRESS (MPA)     42.5    63.8    85.0   106.3   127.5   148.8   170.0   191.3   212.5   233.8   255.0   276.3   297.5   318.8
DAMAGE (MF)    2000.0   418.6   246.4   188.2   654.1  1697.8  1378.6  1314.7  2062.4  1855.2   758.3   301.7   179.4   303.2


ANOTHER CHANNEL? (Y/N): N

END OF EXECUTION
CPU TIME: 2.38  ELAPSED TIME: 1:13.78
EXIT
```

[illegible] RUN.

[illegible] data as for the two [illegible]

[illegible] PROGRAM.

```
SUPPRESS TTY OUTPUT? (Y/N): N
WRITE NEW DAMAGE FILE? (Y/N): Y
DAMAGE FOR ALL STRAIN CHANNELS REQ'D? (Y/N): N


CHANNEL NO=? 1
AIRCRAFT NUMBER AAAAAXXXXX
DATE            02/01/78
CHANNEL     1
BOTTOM LEVEL      = -500.00 (MICROSTRAIN)
LEVEL SIZE        =  135.00       "
YOUNG'S MODULUS= .1700E+06 (MEGAPASCAL)
SN DATA USED FLAGGED BY ISNF=  1
TOTAL DAMAGE TO 02/01/78    =  84023.32 (MICROFAILS)
DAMAGE SINCE     01/01/78   =  13713.46      "
DAMAGE DENSITY HISTOGRAM.
ALTERNATING
STRESS (MPA)     23.0    34.4    45.9    57.4    68.9    80.3    91.8   103.3   114.8   126.2   137.7   149.2   160.6   172.1
DAMAGE (MF)    1476.4  2268.5  4505.0  7914.7 11602.1  9590.2  9881.0  9257.2 10289.1  9374.2  2137.3  3465.6   730.5  1511.3


ANOTHER CHANNEL? (Y/N): N

END OF EXECUTION
CPU TIME: [illegible] ELAPSED TIME: 47.58
EXIT
```

The output file that follows differs from the [illegible] that have the data for one [illegible]

DAMAGE DATA FOR
AIRCRAFT NUMBER AAAAAXXXXX
DATE 02/01/78

CHANNEL 1
BOTTOM LEVEL = -500.00 (MICROSTRAIN)
LEVEL SIZE = 135.00 "
YOUNG'S MODULUS= .1700E+06 (MEGAPASCAL)
SN DATA USED FLAGGED BY ISNF= 1
TOTAL DAMAGE TO 02/01/78 = 84023.32 (MICROFAILS)
DAMAGE SINCE 01/01/78 = 13713.46 "
DAMAGE DENSITY HISTOGRAM:

ALTERNATING														
STRESS (MPA)	23.0	34.4	45.9	57.4	68.9	80.3	91.8	103.3	114.8	126.2	137.7	149.2	160.6	172.1
DAMAGE (MF)	1476.4	2268.5	4505.0	7914.7	11602.1	9590.2	9881.0	9257.2	10289.1	7374.2	2137.3	3485.8	730.5	1511.3

CHANNEL 2
BOTTOM LEVEL = -450.00 (MICROSTRAIN)
LEVEL SIZE = 150.00 "
YOUNG'S MODULUS= .1700E+06 (MEGAPASCAL)
SN DATA USED FLAGGED BY ISNF= 1
TOTAL DAMAGE TO 01/01/78 = 129064.38 (MICROFAILS)
DAMAGE SINCE 00/00/00 = 129064.38 "
DAMAGE DENSITY HISTOGRAM:

ALTERNATING														
STRESS (MPA)	25.5	38.3	51.0	63.8	76.5	89.3	102.0	114.8	127.5	140.3	153.0	165.8	178.5	191.3
DAMAGE (MF)	3386.0	3815.6	8174.4	11517.1	17648.2	17783.1	17181.7	13540.7	15327.7	10780.7	4917.0	2061.9	1249.5	1680.6

CHANNEL 3
NOT A STRAIN CHANNEL

CHANNEL 4
BOTTOM LEVEL = -200.00 (MICROSTRAIN)
LEVEL SIZE = 250.00 "
YOUNG'S MODULUS= .1700E+06 (MEGAPASCAL)
SN DATA USED FLAGGED BY ISNF= 3
TOTAL DAMAGE TO 01/01/78 = 32955.59 (MICROFAILS)
DAMAGE SINCE 00/00/00 = 32955.59 "
DAMAGE DENSITY HISTOGRAM:

ALTERNATING														
STRESS (MPA)	42.5	63.8	85.0	106.3	127.5	148.8	170.0	191.3	212.5	233.8	255.0	276.3	297.5	318.8
DAMAGE (MF)	8.9	2.1	42.0	773.2	2770.[illegible]	4988.4	5245.4	4718.8	5830.9	4375.0	2095.7	872.3	520.0	712.7

DISTRIBUTION

	COPY NO.
AUSTRALIA	
Department of Defence	
Central Office	
Chief Defence Scientist	1
Deputy Chief Defence Scientist	2
Superintendent, Science and Technology Programs	3
Australian Defence Scientific and Technical Representative (UK)	4
Counsellor, Defence Science	5
Joint Intelligence Organisation	6
Defence Library	7
Assistant Secretary, D.I.S.B.	8-23
Aeronautical Research Laboratories	
Chief Superintendent	24
Library	25
Superintendent - Structures Division	26
Divisional File - Structures	27
Author: R.C. Fraser	28
A.K. Patterson	29
P.J. Howard	30
D.G. Ford	31
C.K. Rider	32
Materials Research Laboratories	
Library	33
Defence Research Centre Salisbury	
Library	34
Engineering Development Establishment	
Library	35
Industry Development Branch	
Director (Attn. Mr. Pugsley) (South Australia)	36
Mr. K. Jeeves (Canberra)	37
Mr. J. Patterson (Canberra)	38
Navy Office	
Naval Scientific Adviser	39
Army Office	
Army Scientific Adviser	40

DISTRIBUTION (CONTD.)

	COPY NO.
Air Office	
Air Force Scientific Adviser	41
Technical Division Library	42
D.Air Eng.-AF	43
HQ Support Command (SENGSO)	44
Department of Productivity	
Mr. T. Murray (Marketing Branch)	45
Department of Transport	
Airworthiness Group, Mr. K.O'Brien	46
Statutory, State Authorities and Industry	
Qantas, Library	47
Trans Australia Airlines, Library	48
Ansett Airlines of Australia, Library	49
Commonwealth Aircraft Corporation, Manager of Engineering, (Mr. R. Beckett)	50
Hawker de Havilland Pty Ltd., Librarian, Bankstown	51
British Aerospace Australia (Attn. Mr. A. Waugh)	52-61
SPARES	62-71